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THE INSTITUTE OF PETROLEUM

AN Ordinary General Meeting of the Institute of Petroleum was held at 26 Portland Place, London, W.1, on 12 March 1952, Mr H. C. Tett, vice-president, presiding.

THE CHAIRMAN, opening the meeting, said: Our president, Mr Southwell, is away in the Middle East, and I know he would wish me to convey to you his regret that he is unable to be here to occupy the Chair this evening.

On the very interesting subject of alcohol motor fuels we have two papers. The first is by S. J. W. Pleeth and deals with the production and use of these fuels, and the second is by T. C. Owtram on the economic aspects of alcohol in motor fuel.

The papers should provide a useful and perhaps controversial discussion. Our two authors are experts on the subject. Mr Pleeth is a pioneer in the field of the use of alcohol in motor fuels; he has been in the oil industry for twenty-five years, and for most of that time he has been associated with a company which has developed the use of alcohol in motor fuels in the U.K. Mr Owtram began his career in law, I believe, then moved into the oil industry and was eventually diverted from law into economics; I am told that for some years he has been studying the effects of legislation on our industry.

The following papers were then presented:

ALCOHOL MOTOR FUELS

PRODUCTION AND USE

By S. J. W. PLEETH (Fellow) *

SUMMARY

The production of ethyl alcohol by fermentation and by synthesis. The production of anhydrous alcohol. The use of ethanol as an additive to gasoline, and its effect on calorific value. The thermal efficiency of the engine. Octane numbers and road tests. Anti-knock effects of ethanol compared with that of tetra-ethyl lead. Anomalous vapour pressure of alcohol blends; vapour lock and startability.

The marketing of alcohol blends. The necessity to exclude water. Water tolerance and the safety margin of the blend.

INTRODUCTION

PERHAPS the greatest change observable over the last decade is the alteration of emphasis from the age-old fermentation method for the production of ethyl alcohol to synthetic methods. That is not to say that the fermentation method is obsolete; on the contrary, ferments are being applied to ever-widening fields of activity, notably in the production of anti-biotics,

* Chief Chemist, Cleveland Petroleum Co. Ltd.

where micro-organisms, quietly following their normal life-cycle, are producing metabolistic by-products that can be obtained in the factory only under conditions of high temperature and pressure.

Nevertheless, until means can be found to utilize economically the enormous agricultural waste products, the requirements for fermentation compete with those for food, and with the growing world population the latter must take precedence.

On the other hand, there exists a plentiful source of raw material for the synthesis of the lower alcohols in natural gas, and the gases obtained as by-products of the cracking of petroleum residues. A further supply of raw material is available from coal.

The growing importance of natural gas and cracker gas for the production of ethanol is clearly revealed in Fig 1, relating to the U.S.A. The upper

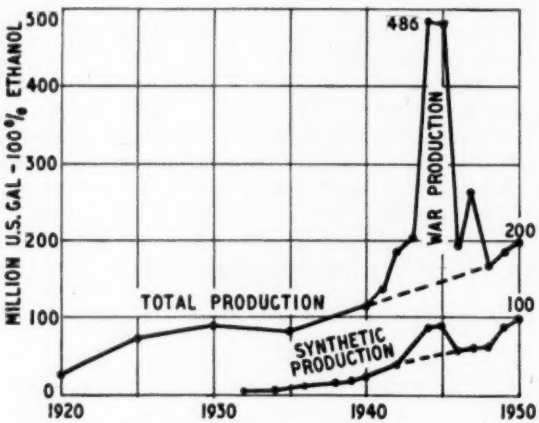

FIG 1

ETHANOL PRODUCTION IN THE U.S.A.

curve shows the total ethanol production for that country. The peak in the curve represents the abnormal war years, where ethanol became an essential step in the production of artificial rubber, and any means were utilized to obtain the highest production. The production of 486 million gallons was achieved largely by the uneconomic use of edible grains for fermentation, and the mobilization of every whisky distillery.

The production curve has been smoothed out by ignoring this abnormal production as indicated by the dotted line. The steady growth in production is evident.

The lower curve in Fig 1 shows the production of ethanol by synthetic methods, largely from natural gas and cracker gas. Again the abnormal war years are smoothed out.

If the two curves are compared it will be seen that the increase in production is due almost entirely to the increase in synthetic ethanol. The production of fermentation ethanol was 93 million gallons in 1930, 85 million gallons in 1940, and 100 million gallons in 1950; while the production of

synthetic ethanol was nil in 1930, 27 million gallons in 1940 and 100 million gallons in 1950, 50 per cent of the total output.

Britain must be guided by this example. The large refinery programme will yield ethylene and propylene in amounts sufficient to produce considerable quantities of ethanol and *iso*propanol. Such production is more in the nation's interest than the dissipation of these valuable raw materials as boiler fuel. At least two plants in the U.K. now produce ethanol from petroleum.

Table I indicates the rapid growth of interest in alcohol motor fuel from

TABLE I

Consumption of Ethanol as Motor Fuel

	Gallons
1932	20,000
1933	80,000
1934	350,000
1935	1,000,000
1936	900,000
1937	3,000,000
1938	6,500,000
1939	6,700,000

its introduction to the British market in 1932. It must be remembered that the consumption of the alcohol blend is from six to ten times that of the alcohol itself.

PRODUCTION

The production of alcohol falls conveniently into two classes—fermentation and synthesis.

Fermentation

Throughout recorded history Man has fermented sugar-containing materials to obtain an alcoholic beverage. The chemical reactions involved are astonishingly complex, and not completely elucidated. In simple terms alcohol is a by-product of the life process of yeast. There are many organisms that cause fermentation, but for alcohol production one stands supreme—*Saccharomyces*—and in particular the strain known as *cerevisiæ*.

Placed in a suitable sugar solution *saccharomyces* grows. If air is blown into the solution, growth is rapid, and the yeast multiplies prodigiously. This is the commercial process for the production of edible yeast. But in the absence of air, growth is accompanied by the production of ethyl alcohol, which in concentrations above about 14 per cent is lethal to the yeast.

Under these conditions the main chemical reaction is given by :

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

From this equation it appears that only 67 per cent of the available carbon in the sugar is converted to useful alcohol. Thermodynamically

the position is less wasteful, for no less than 97 per cent of the thermal energy of the sugar reappears in the alcohol.

At present the carbon dioxide is a valuable by-product, but if a considerable expansion is contemplated, steps must be taken to convert the degraded carbon into fuel. (Thus, in the U.S.A. at the peak of the synthetic rubber project in 1944, when nearly 500 million gallons of alcohol were produced, there was an accompanying output of 1000 million lb of carbon dioxide.)

Carbon dioxide may be converted into liquid fuel in two stages : first by reduction to carbon monoxide, and then by means of the Fischer–Tropsch synthesis.[1]

$$CO_2 + H_2 = CO + H_2O \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$CO_2 + C = 2CO \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$3CO_2 + CH_4 = 4CO + 2H_2O \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Equations (2), (3), and (4) suggest means by which the first stage may be accomplished. Equation (5) is a generic Fischer–Tropsch reaction, of which equation (6) is a typical member.

$$2nCO + (3n + 1)H_2 = 2C_nH_{2n+1}OH + 2(n-1)H_2O. \quad . \quad (5)$$

$$4CO + 7H_2 = 2C_2H_5OH + 2H_2O \quad . \quad . \quad . \quad . \quad . \quad (6)$$

The raw materials for the fermentation process are bewildering in their variety : cane-sugar molasses, sugar-beet, grain, potatoes, artichokes, wood, sawdust, sulphite liquor, and many others. Each raw material presents its own problems, of which collection is perhaps the most serious.

The final product of fermentation is a mash containing not more than 14 per cent alcohol (in practice nearer 10 per cent). This mash must then be distilled to remove the water. The type of still used is familiar to the petroleum industry, which indeed adapted the older alcohol still to its more exacting use.

Azeotropic Dehydration.—Unfortunately, ethyl alcohol, with a boiling point of 78·32° C forms with water a binary azeotrope with a boiling point of 78·15° C, and separation is impossible in the normal bubble-cap column. Thus, until comparatively recently commercial alcohol contained upwards of 5 per cent water, and in this condition is miscible only within narrow limits with petrol, so restricting the marketing of an alcohol–gasoline motor-fuel.

Prior to 1920 anhydrous ethanol was an expensive laboratory reagent, but a number of cheap methods of dehydration were developed, and soon anhydrous alcohol was available commercially at a price little above that of the 95 per cent grade. The most important commercial method was azeotropic dehydration.

The theory of azeotropic dehydration was stated by Young in 1902.[2] He found that benzene formed a ternary azeotrope with ethanol and water with a boiling point of 65° C (containing 74 per cent benzene, 19 per cent ethanol, and 7 per cent water), and this could be readily separated from both pure ethanol (b.p. 78·32° C) and the binary azeotrope ethanol–water (b.p. 78·15° C). Moreover, by ensuring excess of benzene, the binary

azeotrope benzene–ethanol (b.p. 68·25° C) could also be separated from ethanol, which could then be obtained in a high degree of purity. The only drawback in the method is the large bulk of azeotrope that must be handled compared with the amount of water to be removed. For example: to remove 5 gallons of water from 100 gallons of 95 per cent ethanol no less than 50 gallons of benzene must be used; the volume of azeotrope to be handled is nearly 80 gallons. For this reason other entraining agents have been suggested, notably tri-chlor-ethylene [19] and ether.[20] The benzene process, as representing that most widely used in the U.K., will be described.

Fig 2 shows a simplified flow diagram of a typical plant. Dilute ethanol

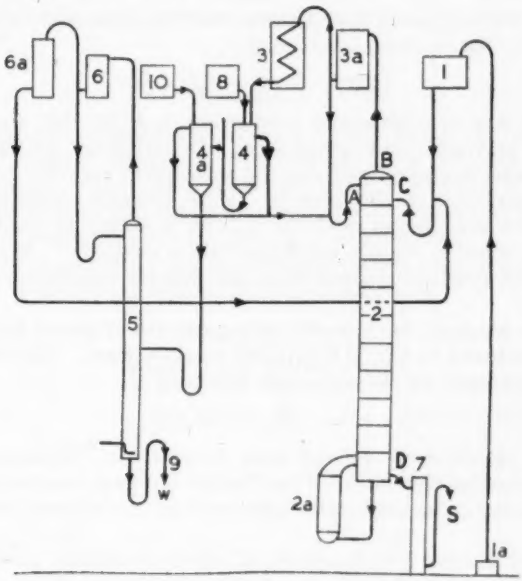

Fig 2

solution (derived from fermentation or synthesis) is distilled in a normal multi-plate column to yield material of 95 per cent strength. This is fed into the dehydrating column 2 at *C*, where it meets benzene (introduced into the column at *A*). The ternary azeotrope formed distils over at *B*. Some of this distillate is returned to the column via dephlegmator 3*a* to form a reflux stream.

The ethanol, stripped of its water, passes down the column and is removed to storage at *D*, first being cooled in condenser 7. The water content has been reduced to below $\frac{1}{2}$ per cent; the benzene content is negligible.

The balance of the ternary azeotrope is cooled in condenser 3 and separated in 4. The upper layer, containing most of the benzene, is returned to the column at *A*, together with a small amount of make-up benzene from tank 8, to replace losses. The lower layer in 4 passes to an auxiliary

separator 4*a*, where water is added from tank 10 to induce a further separation of benzene, which is returned to the column at *A*.

The lower layer in 4*a*, containing almost no benzene, is passed to a small column 5, where it is distilled to recover the alcohol at 95 per cent strength, which joins the main feed in the dehydrating column, leaving a residue of water, which is run to waste at 9.

The entire process is continuous. It is normally combined with the recovery of valuable by-products from fermentation; at all points heat exchangers ensure that the heat loss is a minimum.

Synthetic Methods

Payen in 1863 suggested that ethanol could be obtained by the hydration of ethylene.[3] The reaction involved is

$$C_2H_4 + H_2O \rightarrow C_2H_5OH \quad . \quad . \quad . \quad . \quad . \quad (7)$$

The method was in commercial production in 1919,[4] but the difficulties encountered prevented its extensive use. In particular, the sulphuric acid catalyst became contaminated and the subsequent recovery too costly for economic operation of the process. More recently, however, superior catalysts have been found, and the process is stated to produce ethanol more cheaply than by traditional fermentation methods.[5] It is evident by the growth of synthetic output that the process can be successful commercially.

Two other alcohols, both useful as ingredients of motor fuel, are being currently produced in the U.S.A. from cracker gases. The first, methyl alcohol, is produced by the water-gas synthesis :—

$$CO + 2H_2 \rightarrow CH_3OH \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

The carbon monoxide is derived from cracker gas; equation 8 may be regarded as the first derivative of the Fischer–Tropsch reaction (equation 5) where n equals 1. In 1949, 105 million gallons of methanol was produced in this way.

The second alcohol is *iso*propanol, of which 90 million gallons was produced in 1949. In this case the raw material was propylene, also found in cracker gas :

$$C_3H_6 + H_2O = (CH_3)_2CHOH \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Taking these three alcohols, all potentially useful as ingredients of motor spirit, it may be seen that no less than 300 million gallons was produced in 1949.[17]

This is by no means the full potential of the industry. It has been estimated that each ton of crude refined produces 7 lb ethylene and 10 lb of propylene.[16] Together with the vast natural gas resources of the U.S.A., a production of 500 million gallons is readily achieved.

In Britain there is no natural gas, and cracker gas must be relied upon solely. If all the ethylene and propylene were used, alcohol production could reach 60 million gallons.

It might be argued that this production is small compared with the annual consumption of over 1500 million gallons of motor spirit. Nevertheless, it must be emphasized that the alcohols should be used not as a

main fuel but as an additive. Used in this way, the production of high-octane fuel would be nearly 500 million gallons, especially if aided by benzole production from coal. Not all cars need to use high-octane fuel; and this amount should be ample to cover our requirements.

Ethanol can also be synthesized from acetylene, but this is commercially feasible only in lands with large off-peak loads of hydro-electricity.[7] A far more useful possibility for the U.K. is the application of the Fischer–Tropsch synthesis using coal as a raw material. Perhaps at the present time it is not expedient to discuss this project, but the time may come when low-grade coal will have to be utilized (other than in our household grates), or the development of underground gasification will provide vast amounts of carbon monoxide and hydrogen, sufficient to justify the large capital expenditure.[8]

Use of Alcohol Fuels

Since the internal-combustion engine is a heat engine, the first criterion should be its thermal efficiency. Thermal efficiency is a vector quantity, the components of which are the calorific value of the fuel used and the efficiency with which this heat is converted into useful work, which in the case of the I.C. engine varies with the compression ratio.

Table II lists the calorific values of various fuels; Table III the relationship between compression ratio and thermal efficiency.

Table II

Calorific Value of Motor Fuels

Fuel	Calorific value	
	B.Th.U/gal (nett)	As percentage of gasoline
Gasoline (sp. gr., 0·740)	140,000	100
Ethanol	92,000	66
Methanol	67,000	48
*iso*Propanol	101,000	72
Motor benzole	150,000	108
15/15/70 (ethanol/benzole/gasoline) blend	135,000	97

Table III

Compression Ratio and Thermal Efficiency of I.C. Engines

Compression ratio	Thermal efficiency (actual), per cent
4	27
6	35
8	39
10	43
12	46

From Table II it is evident that if all fuels were utilized with the same thermal efficiency, ethanol would provide only two-thirds the mileage per

gallon given by gasoline. In practice, ethanol is rarely advocated as a fuel by itself; it is normally used as an ingredient of a motor fuel. The last entry in the Table indicates a typical marketed alcohol motor spirit, containing 15 per cent ethanol, 15 per cent benzole, and 70 per cent gasoline. Such a blend has a calorific value only 3 per cent less than gasoline alone. Thus, if gasoline gave 30 miles per gallon in a given car, this blend would show 29 miles per gallon, a scarcely appreciable difference. (Nevertheless, in aviation practice, where synthetic fuels of 100+ octane rating may be used, this discrepancy is sufficient almost to eliminate the use of alcohol as a constituent of aviation fuel.)

Fortunately, fuels are not alike. Ricardo showed in 1920 that ethanol could withstand a compression ratio exceeding 7½ to 1 in his E35 variable-compression engine.[13] (In certain racing engines ethanol has been used

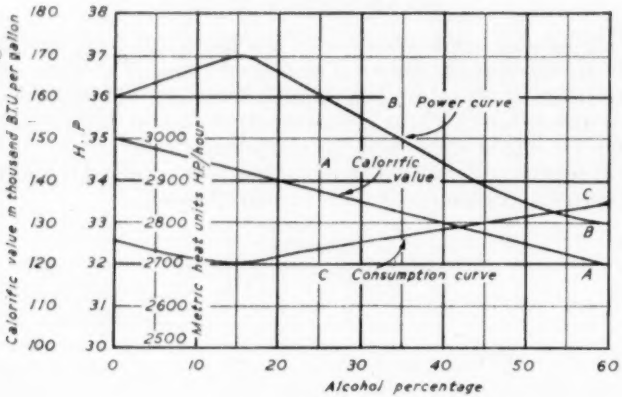

FIG 3

at compression ratios of 12 to 1 without knocking.) Thus, if the relative efficiency of ethanol at say 12 to 1 compression ratio is compared with that of gasoline at a typical figure of 6 to 1, the disparity between their calorific values disappears.

This effect has been clearly shown by Hubendick[9] in a chart (Fig 3). Curve A indicates the normal fall in calorific value due to increasing alcohol content of a gasoline/alcohol blend. Curve B shows the higher power output attainable with the use of this increasing alcohol content. Finally, Curve C shows the corresponding fuel-consumption curve. It can readily be seen that the higher efficiency of alcohol permits an increase in power output (and corresponding reduction in fuel consumption) up to 15 per cent alcohol content. This curve is accepted as the basis of most marketed blends, the maximum alcohol content of which is restricted to 20 per cent. In the early days of alcohol motor fuels unsatisfactory operation has been reported where higher alcohol contents were used (for example, the pre-war "poids lourds" containing up to 50 per cent alcohol.)

Octane Numbers

The arbitrary centisimal scale of octane numbers was introduced by Edgar [14] in 1927 to permit knock rating by different observers to be compared. The knock ratings are compared with blends of *n*-heptane and *iso*-octane, the octane number being the percentage of *iso*-octane in the matching blend. By using a standard CFR engine under standard conditions, comparisons of various fuels can be made. This scale permits a more precise statement of the anti-knock value of a given fuel than does Ricardo's more easily understood Highest Useful Compression Ratio, and provides a simpler test procedure.

Since the scale is an arbitrary one, it must be standardized against tests with motor vehicles on the road. Unfortunately, no standard road tests have been conducted in Britain, and American results must be used. The first American tests were conducted in Uniontown in 1932. They showed low correlation with the knock-ratings obtained on the CFR engine, and the

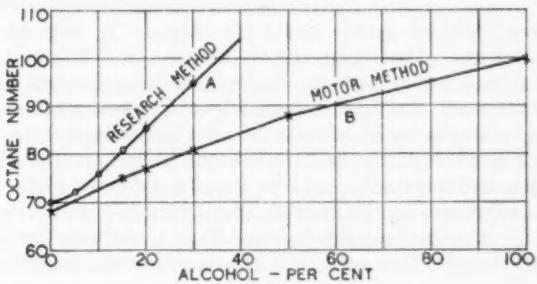

FIG 4

COMPARISON BETWEEN MOTOR AND RESEARCH METHODS (CFR ENGINE).

test conditions were altered to provide a closer correlation. These new conditions were called the CFR Motor Method, while the tests obtained on the original conditions were called the CFR Research Method.

Several further series of road tests have been conducted since that time. After each test modifications were suggested to the basic procedure to provide a close correlation. The situation was becoming so chaotic that wisdom prevailed, and now knock ratings are recorded on two scales—Research Method and Motor Method. A knowledge of both ratings affords a reasonable picture of the behaviour of the fuel, particularly with regard to the "sensitive" fuels, as fuels containing benzole and the alcohols are called.

The effect of test conditions on the knock ratings of ethanol blends is clearly shown in Fig 4, drawn from the author's results.[10] Curve A shows knock ratings of ethanol blends obtained by the Research Method; 36 per cent ethanol raises the octane rating of 70 octane gasoline to 100, indicating a blending octane number for ethanol exceeding 150. Curve B shows the results obtained on these blends determined by the Motor Method. Here the blending octane number of ethanol is about 110 within the marketable ranges of 10 and 30 per cent ethanol; while the octane number of pure ethanol is equal to that of *iso*-octane itself (100). (Since the two standard

fuels *n*-heptane and *iso*-octane are themselves similar to gasoline, any alteration in conditions of test merely moves the entire scale up or down, leaving the relative actual octane number comparatively unaltered. But when fuels containing alcohol are used a similar alteration in operating conditions does not have similar effects on the two dissimilar fuels. This is the reason for the so-called " sensitivity " of alcohol blends.)

There is a growing body of opinion that the true knock rating of a fuel is better expressed by the Research Method than by the Motor Method (for example, see Ref 12).

Road Tests

Road tests are notoriously unreliable and therefore abjured by the fuel technician, who prefers the solid reproducibility of bench tests. One factor appears consistently to be overlooked. Let us consider a car being driven at uniform speed along a level road. Wishing to accelerate, the driver opens the throttle and permits a greater flow of air into the engine.

The sudden increase in air speed (or increase in induction vacuum) causes a greater flow of fuel from the carburettor jet. Ethanol is a volatile spirit, and in conjunction with the hydrocarbons in gasoline forms readily vaporized azeotropes, an effect increased by the presence of benzene. This vapour readily enters each cylinder in turn and, since it contains more alcohol than the whole of the fuel, has an especially high anti-knock value. The driver has the impression that he is using a fuel of higher anti-knock value than is expressed by the knock rating of the fuel itself, for the method of test calls for sustained equilibrium conditions, not snap judgments.

Now contrast this effect with that obtained when a leaded fuel is used. Tetra-ethyl lead is non-volatile, and tends to lag behind in the fuel stream as liquid droplets. The vapour entering the cylinders after a sudden opening of the throttle tends to have a *lower* anti-knock value than the fuel as a whole, for there is less lead present than in the fuel as a whole. This effect is well known to those who have operated a CFR or other test engine. When changing from an unleaded fuel to a leaded fuel of the same knock rating there is an immediate increase in the knock owing to the time lag in the entry of the lead into the cylinder. The operator is unperturbed, for the effect is anticipated, and in any event the method of test calls for a number of check tests extending over 10 or 20 minutes, by which time equilibrium conditions prevail. But the normal driver on the road judges by the immediate response. He would record that the leaded spirit knocked heavily; the straight spirit slightly; and the alcohol blend not at all. He will not listen to the bench-bound technician who assures him that all three fuels have identical knock ratings.

Another factor which tells against leaded fuels, perhaps unfairly, is also due to the non-volatility of the tetra-ethyl lead. The lead enters each cylinder within droplets of fuel and, owing to faulty distribution in the induction pipe, some cylinders are starved and others receive excess lead. (Tests have shown variations from 1 to 6 ml TEL/gallon in different cylinders using a fuel containing 3 ml/gallon.) The normal driver judges the quality of his fuel by the amount of knock. He would estimate the knock rating of his fuel by that corresponding to the lowest lead content

in the various cylinders, and would again de-rate the fuel as compared with the finding of the knock tester, who has but one cylinder. Ethanol, a volatile fuel, enters each cylinder as uniformly as the induction system permits, and does not present this anomaly.

Power Output

It is sometimes wondered why ethanol can produce substantially the same power outputs as gasoline from a given engine, despite the disparity in calorific value. Ricardo has answered this question.[13] For the complete combustion of 1 lb of gasoline approximately 15 lb of air are required; for the combustion of a similar weight of ethanol only 9 lb of air are needed. Thus the 16 lb of air/gasoline mixture has a calorific value of 20,000 B.Th.U. or 1250 B.Th.U/lb, while the 10 lb of the ethanol/air mixture has a calorific value of 12,800 B.Th.U. or 1280 B.Th.U/lb, substantially the same figure. This coincidence is remarkable, and need not occur with other fuels. Its effect is that the power output from a given cylinder charge of ethanol or of gasoline is substantially similar.

Latent Heat

The air/fuel charge introduced into the cylinder consists of a vapour with a number of unvaporized fuel particles in suspension. The power available from that charge depends upon its weight, which in turn depends upon its temperature. When a liquid vaporizes it abstracts heat from its surroundings; the amount of heat abstracted is called "the latent heat of vaporization" of that liquid. The effect is observed when an engine is running, by the lower temperature of the carburettor compared with the rest of the engine; sometimes it is coated with frost, when the engine is appreciably warm.

Not only is the external wall of the carburettor cold, but also the vapour within it; the temperature drop is proportional to the latent heat of the evaporating liquid. Most gasolines have a latent heat of approximately 75 cal/g; the latent heat of benzene is 94, of ethanol 204, and of methanol 264. Assuming total evaporation, the fall in temperature would be 21° C for gasoline, 26° C for benzene, 86° C for ethanol, and 140° C for methanol. In practice, the fuel is not totally vaporized even within the heated cylinder; nevertheless, a marked effect is observed with different fuels. Ricardo has recorded the following values for the induction temperatures within an engine operating under standard conditions on various fuels: gasoline 258° F, benzene 235° F, and ethanol 150° F.[13]

Since vapour becomes denser with reduction in temperature, the lower the induction temperature the greater the charge weight. And since the power output depends upon the charge weight, the lower temperature is preferred. The lower induction temperature associated with ethanol ensures a higher volumetric efficiency, a mild supercharge effect.

In racing engines, especially those using high supercharge, a reduction in charge temperature is essential, and for that reason alcohol is almost obligatory. At one time complex mixtures were used containing ethanol, acetone, and water (which has a latent heat of 540, over double that of ethanol), but nowadays methanol (with a latent heat of 264) is the preferred fuel.

Startability and Vapour Lock

Alcohol fuels have been attacked on the grounds that they provide poor startability at low temperatures and vapour lock at high. Neither of these statements is true, for they are based upon an error. In fact, alcohol in the proportions normally used has little effect upon startability and vapour lock, which are functions of the basic gasoline in the blend. The origin of the error is interesting. Vapour lock is measured by vapour pressure, and the normal method for the determination of this characteristic is by the Reid bomb (IP 69/45).[11] A standard volume of spirit is shaken with four times its volume of air at 100° F, and the final pressure, corrected for the water vapour present, is taken as the vapour pressure. But the method demands the presence of water in the initial stages, and this amount of water is sufficient to cause a normal alcohol blend to separate into two phases. As it happens, the vapour pressure of an alcohol/gasoline blend is higher than the sum of the partial pressures of the two phases, so that the unwary experimenter records a lower vapour pressure than the blend would give.

When vapour-lock tests are made, and two fuels are compared, one a gasoline and the other an alcohol/gasoline blend of apparently similar vapour pressure, it follows that the latter shows a greater tendency to cause vapour locking, and it is on such grounds that the claim has been made. When the true vapour pressures are compared, however, the alcohol blend has a higher value, and could be expected to show a greater tendency to vapour lock. If now the tests are repeated using fuels of equal vapour pressure, no difference in vapour-locking tendency can be found. The effect is recognized in the standard method for the determination of vapour pressure, where the use of a dry bomb is recommended, thus preventing the separation of the alcohol blend into two layers.

Perhaps the only foundation for complaint in startability tests refers to the warming-up period. Owing to the higher latent heat of ethanol, the induction temperature is lower than that found with gasoline, and in winter this tends to reduce the power output from a cold engine. With normal induction heating the effect is slight and of short duration.

Many other differences have been reported between gasoline and alcohol/gasoline blends in an engine, but the effects are either so slight or so dependant upon chance conditions, that there seems little point in enlarging upon them here. The facts may be found in published work, by the writer and others. This section can best be concluded by a quotation from Hubendick, head of the Swedish Government's Fuel Agency, when he reported the results of ten years' operation of the official Swedish alcohol fuel "Lattbentyl": "The public are unaware that the alcohol blend they are using is in any way different from normal gasoline."[15]

Marketing of Alcohol Blends

In only one respect is the marketing of alcohol blends different from the marketing of, say, benzole mixture or gasoline, and that is the rigorous care with which water must be excluded.

Main Storage Installations

Normal alcohol blends are made in comparatively small batches of between 10,000 and 50,000 gallons. The blending tank is one known to be free from water. First the gasoline is introduced and then the benzole if any, added. It sometimes happens that on mixing, such a blend deposits a small amount of water, for benzole will dissolve 0·05 per cent water, much of which will be precipitated from the mixture which has a considerably smaller water solubility. After a short settling time the tank is tested for water (a safeguard against accidental contamination even when no benzole is used), and any present drained off. Finally, the alcohol is added, and the blend circulated until uniform. A simple test has been devised to determine the water tolerance of the blend (that is, the amount of water required to cause separation). Where this figure is satisfactory, proving the absence of water contamination, the blend is available for sale. Normally two or more blending tanks are operated in parallel, so that a blend is available for loading while another is being made.

Given intelligent supervision, blending is not a difficult task. In the writer's experience extending over a number of years only two cases have been encountered of a blend failing owing to ingress of water.

The warning of the dangers of taking laboratory tests as indicative of large-scale results must be repeated. It has frequently been stated that alcohol is hygroscopic, and that alcohol blends absorb water from the atmosphere and eventually "break." These statements may be true enough for laboratory experiments. The author has conducted many such tests, exposing blends to varying degrees of weathering until separation resulted. But never have the results correlated with practice.

Hixon and Fulmer published a similar series of tests.[18] Using 50-ml samples with 2-mm breathing tubes under varying conditions of temperature and humidity, they found that the cloud points rose considerably within fifteen days, indicating water absorption. Repeating the tests with 500-ml samples in litre flasks with the same 2-mm breathing tubes, they found no measurable change in cloud point after 30 days' exposure in the open air. In a large-scale test, using 5,500 gallons of a 10 per cent alcohol blend, they found that the cloud point had risen from −60° C to −58° C in thirteen days. In a final test they observed the behaviour of 84,000 gallons of a 10 per cent alcohol blend. After sixty-six days the cloud point had risen from −60° to −59° C, a negligible deterioration.

Garage Delivery Tanks

Alcohol blends do not normally absorb water from the atmosphere, but care must be taken at every stage of its progress from blending tank to the car tank to ensure that free water is nowhere present. The delivery wagons and the garage storage tanks must be tested for water. These present a problem. They cannot be guarded with the same care as the blender's own storage tanks, and there is an ever-present danger of water from a flooded manhole cover, due to rainfall or a carelessly running hose.

Nevertheless, experience in thousands of garages throughout the country suggests that the danger of water flooding is not great. Remarkably few cases have been encountered. Similar flooding would incapacitate a tank

containing normal petrol, although in this case the gasoline is unharmed after pumping off the water; with an alcohol blend, the tank contents would have to be returned to the main depot, where the aqueous layer would be separated and discarded. Even in this worst eventuality the actual loss of motor spirit is remarkably small.

Absorption of moisture from the atmosphere is extremely small. The behaviour of alcohol blends in garage storage tanks has been observed over many years, and little deterioration has been observed. Normally, the fuel is renewed regularly, but even in remote country garages in winter, with extremely low throughput under wet conditions, the water tolerance falls but little (in other words, the water content increases but little). In an extreme case samples of alcohol blend stored in sealed garage tanks during the recent war showed similar results. True, the material could not be recommended as a fuel, for it had lost its light fractions and possessed a high gum content, but this would have happened with any normal fuel over the same period of storage.

Car Tanks

Finally, to the car tank itself, the most rigorous test of all. Most car tanks contain water, obtained during delivery of normal petrol and by successive condensation. Usually this is held below the fuel-exit pipe and, except in violent swerving, does not reach the engine. At some stage, as the water increases in volume, some finds its way into the carburettor, causing spitting and erratic running. If the trouble persists, the only remedy is cleaning the tank.

When an alcohol blend is introduced into such a tank, trouble might occur if the water content happens to be above a certain figure, corresponding to the water tolerance of the blend introduced. For example, suppose 5 gallons of alcohol blend were introduced into a tank containing water. With a typical water tolerance of 0·5 per cent as little as 1 gill of water could cause separation on a cold day.

It must be pointed out that this trouble is not a frequent occurrence. The writer has had much experience with " broken blends " during the course of experimental road testing, and regards it as a minor nuisance. If the engine is warm, it will continue to operate on a separated blend, for the alcohol concentration in the water layer is sufficient to keep the engine running, unless the water contamination is so gross that the engine would have failed in any case had petrol been the sole fuel. Of course, once the aqueous layer is exhausted, the engine will continue to function on the upper layer, which is mainly petrol.

In starting, a separated blend is fatal. All that can be done is to drain away the aqueous layer, and continue on the upper, petrol layer.

A final word about water : in general, trouble, if any, will be encountered on the initial use. Thereafter the capacity of an alcohol blend to absorb water will prevent the normal deposition of atmospheric moisture.

Conclusion

It is obvious that this short survey can touch upon but a selected few of the many aspects of alcohol fuels. An attempt has been made to state a

case for the intelligent use of alcohol (including the related alcohols—methyl and *iso*propyl—as well as the better known ethyl) as an additive to gasoline, conferring upon the blend certain desirable attributes. The use of alcohol blends as a high-octane motor spirit is no laboratory fancy—it was proved in the pre-war years.

Unfortunately its return in the immediate future is retarded by the heavy demand for ethanol in industry. Most of this ethanol is at present derived from fermentation. The petroleum industry, which has the raw material and the means for its conversion, must be looked to to ensure that this valuable commodity is made available in bulk, both for its own immediate advantage and for industry as a whole.

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ECONOMIC ASPECTS OF ALCOHOL IN MOTOR FUEL

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Summary

The economics of blending: comparative cost of the various means of improving the anti-knock value of motor gasoline. Industrial alcohol prices in U.S. Cost of ethyl alcohol from molasses and from other agricultural materials.

Compulsory blending of alcohol with motor fuel: its adoption, in the inter-war years, by a number of countries, as a means of combating agricultural depression and reducing requirements of foreign currency.

Alcohol blending in France: its relation to the growth of the French beet-sugar industry. Alcohol in other countries: evaluation of excess cost to the community, direct and indirect, due to the compulsory blending of alcohol with gasoline in certain countries in 1950.

The Economics of Blending

Economics is concerned with means rather than ends and, particularly, with the relative advantages of different means of reaching any given end. Since the advantage of using one rather than another equivalent fuel is normally decided by relative cost, an attempt is made in this paper to assess the factors which determine the critical relationship in the case of alcohol-blended as compared with straight gasolines. The paper also examines the circumstances attending the use of alcohol in gasoline in countries where alcohol blends have been marketed on a considerable scale and discusses the economic implications of such use.

Unless otherwise stated, alcohol means ethyl alcohol, since this alone has been extensively used for blending with ordinary motor fuel; for the same reason, it will be mainly concerned with alcohol produced by fermentation. During recent years synthetic production of alcohol from ethylene has greatly increased, especially in the U.S. Growing competition between synthetic and fermentation alcohol may be expected to have important effects on the price of ethyl alcohol, and not only in the U.S., in view of the rapidly increasing production of surplus ethylene from European refineries. But while a reduction of the price of ethyl alcohol would undoubtedly increase the possibility of using it in motor fuel, it is necessary to bear in mind that there will also be alternative outlets, for instance in the chemical field, both for the ethyl alcohol itself and for the refinery gases, which may prove more commercially attractive. There is also methyl alcohol, which should not be passed over without mention, since the fact that it can be produced relatively cheaply from various materials may to a large extent offset the disadvantage of its lower calorific value compared with ethyl alcohol. A mixture of methyl alcohol and higher alcohols can, it is understood, be produced in one synthesis step from carbon monoxide and hydrogen.

Ethyl alcohol is available in greater or lesser quantities in practically every country. In European countries the biggest demand for non-potable alcohol is usually for burning as methylated spirits. From an industrial point of view it has a wide variety of uses, and these include

explosives and, latterly, synthetic rubber, both of which facts give to its manufacture a certain strategic importance.

Mr Pleeth has described the technical merits and limitations of alcohols as engine fuels, and has shown that, blended with gasoline or with gasoline and benzole mixtures, they improve anti-knock value considerably. It is this property that makes alcohol blends worthy of consideration by the ordinary user of motor fuel. Fuels containing alcohol have, in addition, another related but distinct property, that of lending themselves to a high degree of supercharge. This property is of great value for motor racing, but of little to the average motorist, who is interested in the economical running, as well as in the performance of his car.

Let us assume that a refiner desires either to improve the anti-knock value of his regular grade of motor spirit or to run a premium grade beside it. Various alternative methods of achieving this will usually be open to him, and these will be examined from the point of view of achieving the result required at the lowest cost. Current practice in the industry includes the use of such processes as thermal or catalytic reforming and cracking, combined as a rule with the addition of tetra-ethyl lead. The advantages of blending with alcohol have to be estimated as against the use of one or a combination of the above methods. A refiner will probably also take into account any loss of profit due to the displacement of a part of his own product by alcohol or benzole and will, as a rule, be disinclined to resort to blending unless the saving is very marked. In any case, the test must be whether alcohol can do the job at least as cheaply as the other ways of obtaining gasoline of the required grade. It is fair to say that the cost of improving octane number is reflected in the difference in the prices ruling for the various qualities of gasoline.

Fig 1 shows the prices prevailing for the various grades in the U.S. Gulf market.* Closely similar margins will apply in other countries under normal trading conditions. A simple algebraic formula will, therefore, indicate the premium that a blender can afford to pay for alcohol for incorporation in a given blend.

Let p be the cost of the base gasoline and p^1 the cost of gasoline of the grade which is desired. Let the differential cost $(p^1 - p)$ of this grade be called D. If it is proposed to make a blend containing any percentage (m) of alcohol, the price of which is A, the cost of a gallon of this blend will be $p + m(A - p) + C$, where C represents the other additional costs involved in producing a gallon of the blend. Then, if this fuel is to be competitive with a straight petroleum fuel which costs p^1, it is clear that $m(A - p) + C$ must be $\not> D$.

$$\therefore \quad A - p \text{ must be } \not> \frac{D - C}{m} \text{ or } A \not> \frac{(D - C)}{m} + p$$

The industry seems to have settled down to the view that the optimum

* In the published prices, quality is expressed in terms of Research octane number except in the case of one grade 70–72 octane. This could be expected to have a Research octane number of about 73. Research octane has therefore been adopted throughout as providing the best available yardstick for the comparison of prices over a wide range of qualities and not as an expression of opinion on the relative merits of this and the Motor method for measuring the performance of motor fuels. A blending octane value of 140 Research method has been assigned to ethyl alcohol.

proportion of alcohol to blend is about 15 per cent if a reasonable gain in anti-knock value is to be obtained without reducing calorific value so much as to have a visible effect on the rate of consumption. Since the U.S. price quotations for gasolines are based on the Research method, the use of this scale will be adhered to in this paper. Assuming that the base gasoline used was about 73 octane, Research method, Mr Pleeth's table would give us an improvement of 10 or 11 in Research octane number. On the Gulf price basis, the blended fuel would be worth say 1*d* a gallon more than the base

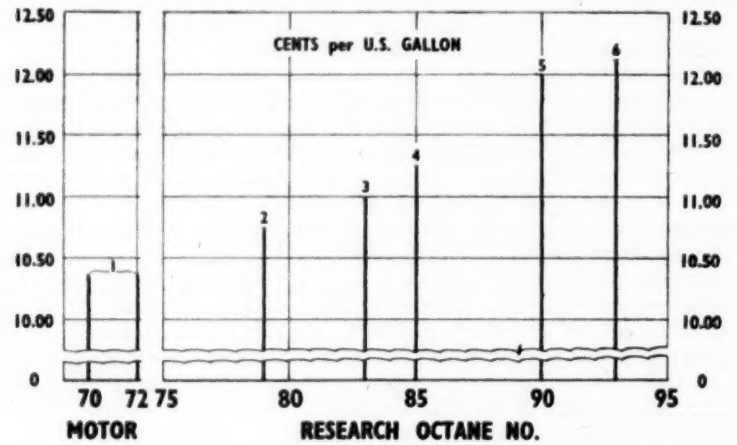

FIG 1

U.S. GULF MARKET GASOLINE PRICES

31 August 1951—Mean of Platts

1 = 70–72 Octane Motor Method Leaded
2 = 79 Octane Research Method Regular Grade
3 = 83 Octane Research Method Regular Grade
4 = 85 Octane Research Method Regular Grade
5 = 90 Octane Research Method Premium Grade
6 = 93 Octane Research Method Premium Grade

gasoline, assuming that it is in other respects the match of a petroleum spirit of the same octane number. Since, in round figures, one sixth of a gallon of alcohol is being put into every gallon of blend, this alcohol could be purchased at 6*d* a gallon higher than the blended gasoline, less the cost of blending. Blending cost includes that of providing special tankage for the alcohol, and of the precautions to prevent either alcohol or blend becoming contaminated with water. While these costs vary according to circumstances, $\frac{1}{2}d$ a gallon of blend might not be an unreasonable figure; this would be equivalent to 3*d* per gallon of alcohol used. In this example, therefore, alcohol would only come into the picture if it was available at a price not more than 3*d* a gallon above the ex-refinery or c.i.f. price of the existing regular grade of motor gasoline.

However, in the last resort the test of the value of a motor spirit is not the laboratory but the preferences of consumers and, judged by this test,

alcohol blends have certain disadvantages which weigh with the ordinary motorist.

Examples could be cited from France, and other countries in which compulsory mixing has been resorted to, showing that a straight gasoline/alcohol blend is not readily accepted by the public as a premium fuel justifying a higher selling price than that of unblended motor gasoline, even if the latter has a rather lower octane number. It follows that a distributor cannot, in practice, necessarily afford to pay a price for alcohol for use as a blending agent which is higher than that of the cost of the unblended gasoline, although in theory it might seem as though he ought to be able to do so.

Experience seems to show that the consumer's critical attitude to straight alcohol/gasoline blends does not apply to blends which include benzole; for example, in France where a blend consisting of gasoline 75 per cent, alcohol 15 per cent, and benzole 10 per cent is successfully marketed as a premium fuel at 3 francs a litre or say 2*d* a gallon higher than that of the regular grade.

However, if the benzole costs more than gasoline of equivalent fuel value, as is the case at present,* the economic price which the blender can afford to pay for the alcohol component obviously must be proportionately reduced. Assuming that n represents the percentage of benzole in the blend and D' the difference (in pence) between the price of benzole and a gasoline of equivalent engine performance, then the maximum premium that the blender can afford to pay for alcohol when benzole also is being included in the blend will be given by :

$$A - p \not> \frac{(D - C)}{m} - (D'/n)$$

Taking D' and n both as 10 :

$$\begin{aligned} A - p &\not> 6(1 - \tfrac{1}{2}) - 1 \\ &\not> 2 \end{aligned}$$

The introduction of these calculations is merely intended to show the *relative* advantage or disadvantage of blending alcohol as compared with adopting alternative means of achieving a similar end in free market conditions. These comparisons of cost are at the manufacturing stage. There are in addition substantially greater marketing costs involved in providing a " premium " grade to meet the requirements of a relatively small section of the consumers. These additional costs, which must be reflected in the selling price of the premium grade, apply equally to a straight gasoline as to an alcohol blend. It may, of course, be quite possible to market an alcohol blend profitably, even if the cost of the alcohol is higher than the formula allows for, when entirely artificial conditions are created in a local market by legislation or by war or something of that kind. Owing largely to world supply and demand conditions, the prices ruling for industrial alcohol in most countries at the present time are such that, except where it is heavily subsidized or its use is made compulsory, alcohol simply does not come into the picture as a potential motor fuel.

* Motor benzole has a controlled price in the U.K. of 2*s* 4*d* per Imp. gal., exclusive of the Excise duty. Export prices are somewhat higher.

The following are typical of recent quoted prices for industrial alcohol in various countries :—

	Price in local currency	Equivalent sterling price per Imp. gal.
U.S.A.	90 c per U.S. Gal.	7*s* 6*d*
France	85 frs/litre *	8*s* 0*d*
Germany	80 pf/litre †	6*s* 0*d*
U.K.	—	10*s* 6*d*

* Cost of beetroot alcohol to the Monopoly (1950).
† Price quoted by the Monopoly to oil companies in 1951.

Moreover, at the present time "priority" uses are absorbing the total supply in some countries.

The present approximate parity between alcohol prices in the U.S. and European countries is quite exceptional. Before the war the price of alcohol in the free American market and in the U.K. was much lower than in the majority of European countries, where a Government monopoly fixed the price. Fermentation alcohol can be most easily and cheaply produced from materials with a high sugar content, for example molasses, of which large quantities are produced as a by-product of the sugar industry, whether cane or beet. Locally produced or imported molasses is the main source material of alcohol in the cane-sugar-growing countries, in the U.S.A. and in the U.K. Although molasses can be used for other purposes, such as for cattle food, its price is largely determined by the demand for industrial alcohol. This is, or at least has been during the last twenty years, a very variable factor.

Fig 2 shows the fluctuations in the U.S. market price of industrial alcohol (*a*) from 1930 to the end of 1949 and (*b*) from January 1950, by months, to middle of 1951 and the related movements in the prices of Cuban blackstrap molasses. The high prices of both alcohol and molasses since the middle of 1950 reflect the consequences of rearmament, and the accompanying high level of demand for alcohol and molasses in the U.S. both for current consumption and for stock piling. This has resulted in the creation of an international price level for these commodities to an extent that was never the case before the war. Imports of molasses into the U.S. have been drawn from a number of other Central and South American countries, as well as from their usual source, Cuba, while considerable quantities of industrial alcohol have been imported from as far afield as France and Finland.

It is impossible to foresee how long it will be before the price curve of industrial alcohol takes a fresh downward plunge such as it took in the years immediately following the war, but the steady growth in the production of synthetic alcohol in the U.S., which increased in the past five years from 67·1 million U.S. gallons or about one-third of the total in the fiscal year 1945–46 to 104 million U.S. gallons, or about half the total in 1949–50 * suggest that any decline in the demand for alcohol or any significant increase in the availability of molasses would bring in a period of intense competition between these two forms of production.

In Europe many different materials are or have been employed in

* 95 per cent alcohol. Source: Stanford Research Institute, "Chemical Economics Handbook."

different countries for the production of industrial or power alcohol. These include grains, tuberous root crops, such as potatoes and sugar-beet, to a certain extent fruits, and in one country, Sweden, sulphite lye produced in the pulping mills. In general, these are high-cost materials compared with molasses. This is not necessarily due to their higher intrinsic value, since in some cases spoilt grain or potatoes have been used. The processing cost with these starchy materials is somewhat higher than for molasses, but the main cost factor is probably in the handling, for, whereas 2½ gallons or about 30 lb of molasses or about 28 lb of maize are required to produce a gallon of alcohol, about 1 cwt of potatoes or sugar-beet are required.

Power-alcohol production in Sweden is a peculiar case in that the

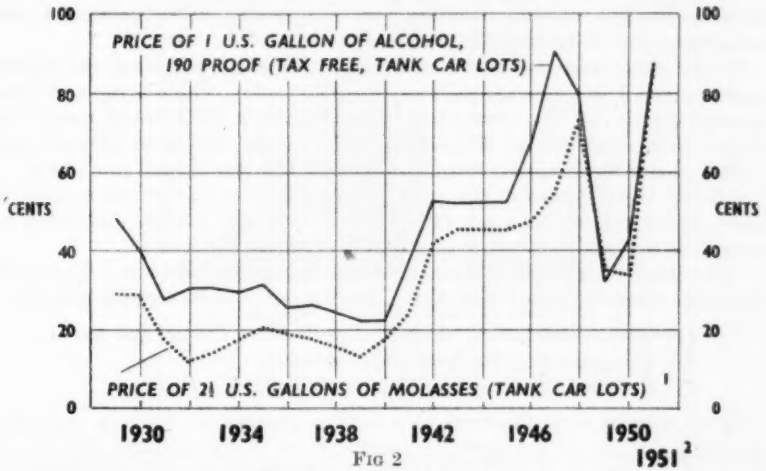

FIG 2

U.S. PRICES OF MOLASSES AND INDUSTRIAL ALCOHOL

Yearly average

1 = About 2½ gal molasses yield 1 gal of alcohol 2 = Average of ten months

material used is an industrial waste product which is actually a nuisance, so that the cost of disposing of it in some other way has to be regarded as an offset against the cost of converting it into alcohol.

High statutory prices were paid for power alcohol before the war in such countries as Germany, France, Italy, and Hungary. As will be seen later, this was due to the fact that the price of alcohol was fixed by Governmental decree at levels which ensured a favourable return to the producer of the raw material.

Compare the following figures relating to 1937 :—

	Raw material used	Raw material cost of 1 Imp. gal. alcohol	Selling price of alcohol per Imp. gal.
U.S.A.	Molasses	10½*d*	1*s* 4*d*
Germany	Potatoes	2*s* 0*d*	3*s* 2*d* *
Italy	Beetroot	1*s* 6*d*	2*s* 2½*d* *
Hungary	Maize	1*s* 1¼*d*	2*s* 6½*d* *

* Price charged to oil companies for dehydrated alcohol.

Compulsory Blending of Alcohol with Motor Spirit

Before the last war alcohol blends were being marketed in eleven European and about twelve non-European countries or colonies, but in fifteen of these countries alcohol blending was compulsory, either nation-wide or in certain areas. In the remaining countries locally produced alcohol enjoyed a very favoured tax situation. In 1950 several countries where alcohol blending was compulsory before the war were behind the iron curtain, and information about these was lacking. But so far as could be ascertained, alcohol blends were being marketed, usually on a limited scale, in some twelve countries. Blending was compulsory in only three European countries (France, Switzerland, and the Irish Republic), though in none of these was alcohol blended with *all* gasoline through the year. Outside Europe, alcohol blending was compulsory in six countries—all countries where cane-sugar is produced.

In the nine countries where compulsory blending prevailed, the higher cost of alcohol as compared with that of the gasoline which it replaced was covered partly by the exemption of alcohol from road taxes, partly by higher prices charged to the consumers, and, in two cases (France and Cuba), partly by direct Government subsidies to the alcohol producers.

Adding these together, the aggregate excess cost of the marketing, in these ten countries, of some 240,000 tons of power alcohol amounted to over £13¾ million, an average of £57 10*s*. a ton (see Table I).

The commercial disposal of alcohol became an acute problem in European countries after the first world war. Among the reasons for this were :—

(1) Over-development of alcohol production during the war.
(2) The growth of the beet-sugar industry.
(3) Reduced consumption of potable alcohol.

While alcohol manufacturers cast envious glances at the large potential market provided by the growing consumption of motor spirit, the cost of alcohol was seldom, if ever, low enough to enable them actually to enter it. During the first decade after the war there was only one important country,

Table I

Analysis of Community Cost Due to Use of Alcohol in Motor Fuel, 1950

(*a*) Country	(*b*) Consumption of power alcohol, m. tons	(*c*) (*b*) as % of total motor-fuel consumption	(*d*) Direct subsidy to alcohol producers, £ per m. ton *	(*e*) Loss of taxes owing to preferential treatment of alcohol, £ per m. ton *	(*f*) Excess costs of alcohol blend passed on to consumer, £ per m. ton *	(*g*) Community cost of alcohol blends ((*d*) + (*e*) + (*f*)), £ per m. ton *	(*h*) Total community cost of alcohol blends ((*b*) × (*g*)), £
			£ *s* *d*	£ *s* *d*	£ *s* *d*	£ *s* *d*	
Australia	11,306	0·65	none	10 2 9	—	10 2 9	114,509
Brazil	19,800	1·28	none	14 16 0	51 9 6	66 5 6	1,312,245
Chile	1,400	0·58	none	8 12 8	29 4 3	37 16 11	52,985
Cuba	47,881	12·26	21 10 5	15 10 10	—	37 1 3	1,882,322
Eire	4,855	2·31	none	16 5 6	40 13 9	56 19 3	276,553
France	81,370	2·99	61 5 0	30 0 0	2 0 0 †	93 5 0	7,587,753
India ‡	10,912	1·82	none	—	—	—	—
Sweden	31,900	5·27	none	25 17 6	—	25 17 6	825,412
Switzerland	20,000	6·49	none	25 0 0	62 16 0	87 16 0	1,756,000
South Africa	7,281	0·63	none	10 0 0	3 2 6 §	6 17 6	50,057

* Per m. ton of alcohol.
† Estimated.
‡ India only; no alcohol used in motor fuel in Pakistan.
§ Gain to consumer; the mixture is sold below the price of straight gasoline.

France, in which the Government gave legislative backing to these aspirations. The events of 1929 to 1931, however, changed the picture in a dramatic way. In 1929, when harvests nearly everywhere were exceptionally large, prices of cereals and other farm products began to fall; the fall in prices soon became catastrophic, and was one of the causes of the world depression which lasted until 1933. During this period, legislation to enforce the blending of alcohol with motor spirit was passed in no less than eight European countries and in five or six cane-sugar-growing countries. Similar proposals were put forward, but rejected after careful examination, in some ten other countries. The main object of this emergency legislation was to provide additional outlets for one of the country's main agricultural crops such as maize, potatoes, or sugar-beet, or to support

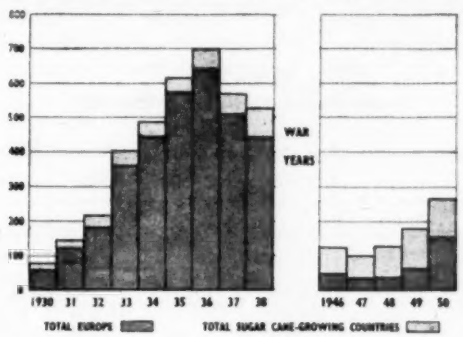

FIG 3

WORLD CONSUMPTION OF ALCOHOL AS AN ENGINE FUEL

Thousand metric tons

the market for it by turning to profitable use some by-product, such as the molasses resulting from the production of sugar. While assistance to the farming community was the main object, other considerations were also involved such as :—

(1) To economize in the use of foreign currency by the partial substitution of an indigenous for an imported fuel.

(2) To support the alcohol industry on account of its strategic importance.

As will be seen from Table II and Fig 3 consumption of alcohol in motor fuel increased from 77,700 tons in 1930 to a peak figure of 700,000 tons in 1936.

Since the war most countries have been bent on maximizing food production in order to save on food imports or to earn foreign exchange by exports of foodstuffs, and there have not been many surplus agricultural products to bother about. It is no doubt for this reason primarily that consumption of alcohol in motor fuel since the war has been on a much smaller scale than during the thirties so that, as shown in Table III, total consumption of alcohol for this purpose in 1950 was less than half the total for 1938. But so long as Governments are inclined to use conversion into alcohol as an emergency exit for any unwanted agricultural products, the

TABLE II

Growth of Consumption of Alcohol as Engine Fuel 1930–38

Metric Tons

	Total Europe	Total sugar-cane-growing countries	Total world
1930	58,700	19,000	77,700
1931	121,000	22,000	143,000
1932	182,270	35,000	217,270
1933	361,650	42,000	403,650
1934	445,340	42,000	487,340
1935	576,448	40,189	616,637
1936	645,853	54,492	700,345
1937	510,272	58,625	568,897
1938	442,399	85,810	528,209

TABLE III

Power Alcohol Consumption 1946–50

Metric Tons

	1946	1947	1948	1949	1950
Europe :					
France	150	4,400	12,100	12,800	81,370
Germany	Nil	Nil	Nil	400	17,400
Italy	Nil	Nil	400	Nil	Nil
Sweden	24,150	9,900	5,550	26,700	31,900
Switzerland	22,000	16,000	14,400	15,000	20,000
Eire	610	3,579	4,372	5,800	4,855
Sugar-cane-growing countries :					
Australia	7,336	4,287	4,456	7,113	11,306
Brazil	9,432	35,656	44,032	44,600	19,800
Cuba	42,281	9,655	20,216	41,343	47,881
India	9,079	6,478	10,475 *	12,565 *	13,202 *
Philippine Islands	Nil	Nil	1,030	4,826	10,770
South Africa	6,763	7,212	7,061	7,733	7,281

* No automotive alcohol used in Pakistan.

problem will be liable to recur, and in a few European countries it shows signs of doing so at the present time.

ALCOHOL IN FRANCE

France is in a sense the motherland of alcohol blending. Blending legislation was first introduced in 1923 because it was politically necessary to find a new outlet for beet alcohol, thereby enabling that of satisfying human needs to be reserved for the alcohol derived from fruits and wine, but up to 1931 the total annual quantities blended with gasoline were relatively small.

A further turn of the screw occurred in 1931, when the effects of over-production and of the world economic depression on the sugar industry led to an international agreement to restrict sugar production. In France the Alcohol Monopoly afforded the producer a guaranteed outlet for alcohol made from beet at a price no less advantageous than that ruling for sugar. This resulted in a big increase in the production of alcohol from sugar-beet.

In the following financial year the quantity of alcohol blended with gasoline consequently more than doubled. (Table IV and Fig 4.)

In July 1935 further legislation was introduced which in effect diverted

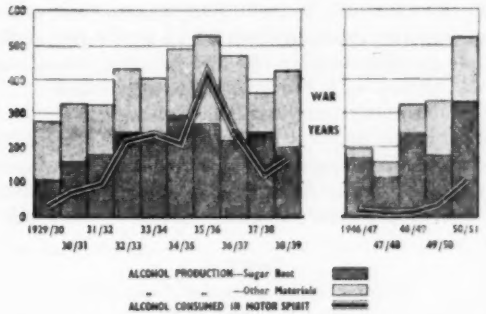

FIG 4

FRANCE—ALCOHOL PRODUCTION, AND CONSUMPTION IN MOTOR SPIRIT

Thousand kilolitres

all types of surplus alcohol into the gasoline market, practically without limit as to quantity.

The cost to the State of the subsidies to alcohol producers plus the loss of duty owing to substitution of alcohol for gasoline now mounted to over 1000 million francs a year.

TABLE IV

France : Alcohol Production and Consumption in Motor Spirit *

	Production—Kilolitres			Consumption
	Materials other than sugar-beet	Sugar-beet	Total	
1930–31	170,867	152,542	323,409	65,139
1931–32	145,307	171,542	316,849	86,420
1932–33	189,693	244,178	433,871	212,883
1933–34	180,824	219,313	400,137	229,871
1934–35	203,683	288,675	492,358	202,218
1935–36	255,250	267,506	522,756	413,001
1936–37	253,195	214,965	468,160	256,682
1937–38	115,072	235,108	350,180	135,808
1938–39	225,679	196,398	422,077	169,310
1939–40	157,654	306,696	464,350	11,446
1946–47	31,904	162,329	194,233	16,709
1947–48	40,489	113,504	153,993	12,642
1948–49	86,206	237,452	323,658	13,624
1949–50 *	157,465	171,535	329,000	39,850
1950–51 †	185,848	327,952	513,800	101,086

* Source : " Le Statut de l'Alcool," Conseil Economique, except for 1949–50 and 1950–51.

† Provisional and partly estimated.

The regulations as to the disposal of this alcohol in motor fuel have varied from time to time in accordance with the amounts needing to be disposed of and ideas prevailing at the time. These ideas have gradually evolved from the early, and as it turned out unsuccessful, one that a 50/50 alcohol-gasoline blend could be sold *pari passu* with ordinary gasoline. The next stage was the incorporation of 25 or 30 per cent of alcohol in commercial grade gasoline, and in the last pre-war phase, which started in 1935, alcohol was mixed with the first grade of gasoline.

It was not until some years after the last war that alcohol blends reappeared on the French market, but early in 1950 the oil companies were requested to assist in disposing of about 50,000 m. tons of alcohol by selling this in an 80-octane premium fuel, consisting of 15 per cent alcohol, 10 per cent benzole, and 75 per cent gasoline. Later in the year, owing to the

TABLE V

France: Sales of Alcohol Fuels, 1950

Thousand Cubic Metres

	Gasoline component	Alcohol component	Benzole component	Total	%
1. Ordinary grade . .	2485	—	—	2485	—
2. Ordinary grade with alcohol (*a*) . . .	278	49	—	327	—
					100
3. Premium grade (*c*) . .	304	—	—	304	—
4. Premium grade (*c*) with alcohol and benzole (*b*) .	223	54	44	321	—
					100
	3290	103	44	3437	

(*a*) 85% gasoline, 15% alcohol, octane rating 70 Motor method (marketed 1 September–31 December, 1950, only).
(*b*) 75% gasoline, 15% alcohol, 10% benzole, octane rating 80 Research method.
(*c*) Gasoline (leaded or plus benzole), octane rating 75 Research method.

greatly increased quantities of beet-sugar alcohol coming forward for disposal, the Alcohol Law passed earlier in the same year was brought into force. Under this, the distributors were obliged to purchase alcohol to the amount of 10 per cent of their gasoline sales and to blend this with their regular gasoline as from September 1, 1950.

After the addition of alcohol to the ordinary grade gasoline began, a big switch on the part of consumers to premium grade was noticeable; the sales of premium grade rose from about 8 to over 50 per cent of the total sales of motor fuel during the last months of the year. Dislike of the binary alcohol/gasoline blend was undoubtedly the principal cause of this shift in demand.

Large export sales of alcohol to the U.S.A. by the French Alcohol Regie resulted in compulsory admixture being suspended after the end of 1950, but the premium grade consisting of gasoline, alcohol, and benzole has continued to be sold. The French Government buying price for sugar-

beet alcohol is fixed under a " parity formula " which relates it to the price ruling for sugar.*

Under the alcohol law of February 1950 beet alcohol was sold to the oil companies by the Regie at a price corresponding to the *duty paid* cost of gasoline.

This worked out in 1950 at 36 francs/litre, whereas the cost of beet alcohol to the Regie, including the cost of dehydration was 85 frs/litre. Therefore :—

Cost of beet alcohol to the Monopoly	85 frs/litre
Selling price	36
Loss to Monopoly	49
As there are no duties on alcohol *add* loss to State in duty	24
Total cost to State	73 frs/litre

In 1950 the cost to the State of subsidizing the use of alcohol in motor fuel was therefore 7500 million francs,† while the total cost of subsidies to alcohol producers exceeded 9000 million francs.

Alcohol in Other Countries

The introduction of compulsory alcohol blending in other European countries was due to basically similar causes, although the form of agricultural production which was assisted differed from country to country. For example, in Germany and the Baltic States potatoes were the main source material for alcohol, and in Hungary maize. In the case of Germany, however, economic self-sufficiency was probably the fundamental objective, thus experiments were made also with mixtures containing synthetic methyl alcohol. During the later thirties the attainment of self-sufficiency in foodstuffs was found to be incompatible with the use of alcohol from potatoes in motor spirit, since an acre or more of potatoes is required to produce a ton of alcohol. Its use was therefore tapered off in Germany, methyl alcohol being substituted for it in progressively greater quantities.

In Sweden legislation regarding the blending of alcohol with gasoline was introduced in 1934, and remained in force until 1947 with the object of providing an outlet for the sulphite lye which is a by-product of the important wood-pulp industry. All motor-spirit importers were obliged to take a certain quota of alcohol equivalent to a small percentage of their gasoline imports, but the composition of the blend sold was left to the discretion of the company.

In 1946 a Government committee was appointed to examine, both from

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* The buying prices for other types of alcohol are a ratio of the price of sugar-beet alcohol. In 1949–50 these were respectively as follows :—

Source material	Ratio	Buying price/litre, frs
Beets and other tuberous and annual plants	1	77·8
Wine	2·7	210
Corn and synthetic alcohol	0·6	46·7
Molasses	0·68	52·9

† *I.e.*, 103,000,000 litres × 73 francs.

the economic and the strategic angles, the desirability of continuing the production of alcohol for use as motor fuel. The Report of this committee has not been made public, but on 1 April 1947, the law making the purchase of alcohol by the oil companies compulsory was suspended. It is known that the Government was influenced by the large fuel consumption involved in the production of alcohol. Alcohol, however, still enjoys a substantial tax advantage over gasoline, and the oil companies are continuing to off-take considerable quantities from the distillers at prices which compare not unfavourably with that of gasoline, and which make it possible to sell the blend at the same price as straight gasoline.

In Switzerland two types of special fuels were introduced in order to eke out supplies of motor spirit during the war.

These were "Ems Alcohol," a blend of ethyl and methyl alcohol produced by the wood-saccharification method by a firm at Ems, and "Para" spirit, which is a mixture of the above alcohol with paraldehyde. These fuels are blended with ordinary gasoline during the winter season. Supply contracts have been entered into which run till 1955, and these products represent at present about 7½ per cent of total motor fuel consumption.

Cane-sugar-growing countries are commonly faced with a problem over the disposal of their molasses, and since such countries are often economically dependent on the earnings of the sugar industry, the conversion of the surplus molasses into alcohol for motor fuel naturally has a strong appeal. It is not surprising that Cuba and the Philippines were the first countries in which alcohol was used for motor fuel on a considerable scale, although such use has developed to a certain extent in all sugar-growing countries, and particularly in Brazil. In the Philippines alcohol has been used as motor fuel to a considerable extent without other assistance than exemption from the duty on gasoline. In Cuba motor fuel distributors are obliged to purchase stipulated quantities of alcohol monthly at prices which will permit blends to be retailed at the same price as straight gasoline, after making allowance for blending and handling costs. Power alcohol is exempt from duties and taxes, and in addition receives a direct subsidy of 18c/U.S. gallon.

In Brazil the production and sale to the oil companies of power alcohol is controlled by a Government organization known as The Institute of Sugar and Alcohol (IAA).

Surplus sugar-cane, as well as molasses, is converted into alcohol, much of which is used locally as industrial or household fuel. In order to ensure continuity in the supplies of alcohol for motor fuel, the IAA obliges sugar refineries to supply fixed quantities of alcohol to the Institute in order to qualify for their sugar quotas, while the price paid for alcohol to the suppliers is fixed in such a manner as to give the producer the same profit, whether the sugar-cane is converted into sugar or alcohol. The quantities of alcohol involved are considerable, but have only averaged about 2·5 per cent of the country's total motor-fuel consumption in the last five years. It is the professed aim of the IAA to raise alcohol production to about three times its present level.

In India, where the growing of sugar-cane has greatly increased in recent years, the Government has, since the war, enforced the blending of alcohol with motor fuel in certain sugar-growing districts. The alcohol has

hitherto been produced without subsidy on a commercial basis and sold to the oil companies at a price which enables the blend to be sold at the same price as ordinary gasoline. The alcohol has not up to the present enjoyed any taxation advantage over gasoline, but it is only marketed in a few inland districts where the high freight on gasoline from the coast to the point of consumption operates as a natural protection for the alcohol.

The commercial sale of alcohol-blended fuels in those countries where it has been practised has either been carried out under legal compulsion or has been assisted by the exemption of alcohol from the heavy rates of duty imposed on motor gasoline. Comparisons between the price of alcohol and that of gasoline show that in the absence of subsidies or duty advantages to alcohol, blending could seldom have been adopted without loss. This is certainly the situation to-day.

But, as has been seen, in many countries there has been an influential body of opinion which saw an economic justification of a wider kind in subsidizing alcohol sufficiently to make it possible so as to use it either, (*a*) to assist particular groups of primary producers, or (*b*) to improve the country's trade balance sheet. The policy of state assistance to agriculture is very firmly established in many countries. Without criticizing the policy itself, one may legitimately ask whether a particular aspect of it is well conceived.

In France there was a net cost to the State in respect of the subsidy to beet alcohol amounting to 73 frs/litre. The amount which went to the farmer in payment for the beet was, however, only the equivalent of 45 frs/litre. The State would have saved a great deal of money had it simply paid the subsidy to the farmer and allowed the beet to be used for cattle-feed and manure.

Some other justification for French alcohol policy seems therefore to be required in addition to the need to assist agriculture. This might be claimed to be the saving of foreign currency due to utilizing a domestic fuel in part replacement of an imported one.

Without discussing the abstract merits of free trade *versus* protection, there are, in the present economic situation, a number of factors which may tend to offset any advantages of such extreme protective measures so far as France and some other European countries are concerned.

These are :—

(1) The recent development of petroleum refining in France and other West European countries, which by substituting crude imports for those of finished products has reduced the proportion of foreign currency represented in the price of a gallon of gasoline.

(2) The heavy consumption of fuel in a distillery.

(3) The high rates of subsidy involved and the cost of these to the revenue.

(4) The fact that when the labour and other resources of a country are already fully employed, devoting such resources to relatively inefficient and costly forms of production has a direct tendency to create or to increase monetary inflation.

In 1949 the French Government requested an impartial and authoritative body, the Conseil Economique, to prepare a study of this question.

Among the conclusions reached in their report, of which use has been made in preparing this paper, were that steps should be taken to bring about a substantial increase in the production of sugar from beet in France, with an accompanying reduction in that of alcohol, and that savings to the State resulting from reduced deliveries of alcohol for blending purposes would enable the necessary expansion of sugar-refining plant to be carried out.

If an undue proportion of this paper seems to have been devoted to an analysis of the position in one country, the answer must be that it is in France that this particular method of coping with the problem of unbalanced agricultural production has been applied and tested out on the biggest scale over the longest period. Study of the French case leaves little further to be learnt from the study of alcohol blending in the other countries where this has been carried on under compulsion.

The question has, of course, in addition to its economic aspects, socio-political ones which could be debated endlessly, and which might be described as " The Ship Money controversy in Reverse," *i.e.*, the question whether the inland producer has a right to be subsidized at the expense of those who go down to the sea in ships, or more strictly, who use the roads in motor cars.

The conclusions of this paper may be summarized as follows :—

(1) The prices now ruling for industrial alcohol are commercially prohibitive as regards the use of alcohol for blending with motor spirit except for racing purposes, but their prices are exceptional.

(2) Nevertheless the ability of alcohol blends to compete price-wise with straight petroleum fuels of equivalent performance in more normal conditions in the absence of any subsidy or tax advantage to alcohol, has still to be proved.

(3) The existence of abundant supplies of ethylene will indubitably result in reductions in the cost of producing ethyl alcohol in European countries, but this will not in itself ensure that ethyl alcohol will be found to be a cheaper blending component for high octane motor fuels than hydrocarbon oils produced by modern refinery processes.

(4) The compulsory blending of alcohol with motor fuel has in many countries been proved to be a costly and inefficient way of assisting agriculture and eliminating agricultural surpluses.

Discussion

Professor F. H. Garner, O.B.E. : Mr Pleeth's book on " Alcohol as a Fuel for Internal Combustion Engines " can be regarded, I think, as the standard text book on this subject. In it he makes the statement, after reviewing the two schools of thought about alcohol blends : " One can scarcely avoid the conclusion that the results arrived at are those best suited to the political or economic aims of the country concerned, or of the industry which has sponsored the research."

I think that does not apply to either of the excellent papers presented here this evening.

The subject has been largely controversial because of the use of the

following arguments: alcohol can be obtained easily from agricultural waste products; alcohol can be home-produced, and therefore expenditure on imported petrol is not required.

Mr Owtram has shown that in fact alcohol cannot be produced as cheaply from agricultural waste products as from hydrocarbons from petroleum sources, and this may be partly due to the ever-increasing efficiency of operation of the petroleum industry. Indeed, as Mr Pleeth has pointed out, the tendency has been for an increasing proportion of alcohol to be made from hydrocarbon sources.

Mr Owtram also shows that there are alternative uses for agricultural raw materials which are probably more suitable than conversion into alcohol.

It is stated by Mr Owtram that the consumer cannot afford to pay a higher price for a straight alcohol–gasoline blend than for a straight gasoline; it would be interesting to have Mr Pleeth's views as to whether he considers that benzole is always necessary.

I think the way in which Mr Pleeth has presented the evaluation of the improvement in octane number is the correct basis of comparison. He said that unfortunately no standard road tests have been conducted in Britain and that American results must be used. In fact, we had observers present at the Uniontown Road tests, and there has been fairly close collaboration with the United States in the whole of this work. His conclusion that "road tests are notoriously unreliable and therefore abjured by the fuel technician, who prefers the solid reproducibility of bench tests" would not be subscribed to by those engaged in the work; and road tests have been carried out continuously in the U.K.

I should like to ask Mr Pleeth a question concerning the Reid vapour pressure of alcohol blends. It was he himself who showed the need for special care in carrying out this test for alcohol blends. Does he, however, think that it is advisable to use a gasoline with a slightly higher volatility than normal in order to obtain starting properties equivalent to those of a straight gasoline?

It would be interesting if Mr Owtram could add to his paper some information concerning the amount of alcohol used in conjunction with gasoline in countries other than France.

In conclusion, Mr Pleeth has said that the papers to some extent represent a discussion of progress made over the last ten years, and he has shown that the one point which has emerged during the last ten years—as indicated quite clearly in his graph—is that the production of synthetic alcohol is now equal to production from fermentation and that the bulk of this alcohol came from petroleum. I think the question is now, what is the best use that can be made of the cracked gases in so far as motor fuel is concerned, whether they should be converted into alcohol or into high octane number hydrocarbons?

MR PLEETH: The economics of this question have been left to Mr Owtram. From Fig 2 in his paper you will notice that in 1938–39 the price of alcohol went down to about 22 cents per U.S. gallon. The price of gasoline was about 12 cents per U.S. gallon; so that there was still a price differential in favour of gasoline as against alcohol. Since then the various

war scares have increased the price of alcohol, because it is used as a war commodity. Since I believe the producers of alcohol were making a handsome profit in 1938–39, I would rather take the price of 22 cents per gallon than the fantastic price which was reached in 1947, when war circumstances and synthetic rubber production raised the price unfairly. I am certain that it can be produced in the United States at about 10 cents per gallon at present, using ethylene from cracker gases, which is considerably cheaper than the gasoline we are compelled to produce or to buy.

The reference to the use of benzole in blends raises the point of the road *versus* the bench test. I have conducted a number of bench tests, using alcohol–gasoline blends, and on the bench there appears to be no difference at all. But on the road the addition of benzole is very effective indeed. I wonder whether a representative of National Benzole Co. would care to add something on that point. Why is it that on the road benzole has an effect which cannot be observed in bench tests? I appreciate, of course, that road tests must be conducted.

With regard to the vapour pressure, it is necessary to use a gasoline of rather higher volatility than motor gasoline when using alcohol.

MR OWTRAM: Regarding the use of alcohol blends in countries other than France, I do not remember all the details, but there is a section in the paper dealing with these other countries. There are about ten countries where alcohol blends are sold. Such blends do not, except in Cuba, form more than a relatively small proportion of the total motor spirit sold. There is considerable variation in the actual composition of the blends used in different countries, but there seems to be a tendency towards including 15 per cent of alcohol, which is about the optimum figure from the consumption aspect, as Mr Pleeth has shown. In many cases the amount of alcohol that is available varies greatly from year to year. That is so in Brazil especially, where it is sometimes equal to 2 per cent of the motor spirit sold and sometimes to 3 or 4 per cent, according to what kind of season the sugar growers have had. Blending does not extend to all districts, and the composition of the blends varies from district to district.

I have not data with me at the moment on the price of gasoline in the United States in 1939, at which time alcohol was costing about 22 cents per gallon wholesale. I think that the 12 cents which Mr Pleeth mentioned as the price of gasoline at that time was more likely the price to the retailer than the Gulf price for bulk cargoes, which I think was a good deal lower than 12 cents at that time.

With regard to the 10 cents per gallon as the cost of synthetic alcohol, without claiming to know for certain, I would accept that as probably the processing cost, if the value of 4½ lb of gas as given is assumed; I do not think it includes the cost of the gas. Of course, the value of that is what it will fetch at the present time.

G. CLAXTON: I think it is very refreshing indeed to find a paper on alcohol which is not based on misconceptions and on bias. Perhaps some of the misconceptions have been carried through since the days when alcohol blends were made with 95 per cent alcohol, and the disadvantages found then have been applied to blends containing anhydrous alcohol. With

regard to bias, when I received the preprint of the paper a few days ago I took the trouble to look up a discussion on a paper on alcohol presented to the World Petroleum Congress in 1933, and to read the remarks of a very important petroleum chemist. Those were the days of prohibition. He said one could get a highball by adding a little water to the petrol in one's car. Then he said that the consumption in a car using "alky gas," as he called it, was 8 per cent lower than when using petrol.

A number of years ago I had the privilege of being connected with some quite extensive tests of alcohol blends, and I can assure you that what Mr Pleeth has said is correct. In bench tests, for carburettor settings above the theoretical air/fuel ratio the effect of changing from a benzole blend to an alcohol blend was to increase the power and reduce the consumption, but at settings below the theoretical ratio the reverse was the case, there being lower power output and greater consumption.

In most cars the carburettors are set on the rich side. When Mr Pleeth criticizes road tests he probably has in mind that reports from drivers with regard to consumption are often so conflicting that one can only conclude that the alcohol blend has exactly the same consumption as a benzole blend.

One other point mentioned in the paper is the lowering of temperature owing to the high latent heat; that undoubtedly causes slower warming up in a car engine. But the prevalence of hot spotting in induction systems should very largely rule that out to-day.

In connexion with the tests I have mentioned, some starting tests were made, and there can be no doubt that the alcohol blend does produce easier starting than does petrol.

In connexion with Mr Owtram's paper I am on less secure ground. I agree that, as a means of feather-bedding the farmer, the compulsory use of alcohol seems to be a quite wrong idea. I was disappointed, however, that neither author made more than passing mention of methanol. I know that it is not as good a fuel as ethanol; but if we are concerned with strategic considerations, methanol, and for that matter ethanol, can be produced from coke oven gas, which I think could produce about 60 million gallons of ethanol a year.

Mr Pleeth has asked why, on the road, the knock rating was very different from that obtained on the bench. That is purely a temperature effect. In the tests mentioned earlier the knock rating tests were done on an E5 engine and different characteristics were obtained on the CFR engine; actually the replacement value of ethanol for benzole was about 2/1 in those conditions.

MR OWTRAM: I did not refer to methanol in the summary, but I did refer to it briefly in the paper, and I agree that it is one of the things about the potentialities of which we have not nearly so much knowledge as might be advisable. It was used to a certain extent in Germany before the war as one of the synthetic fuels developed there to reduce their dependence on imports, but it does not appear to have interested them sufficiently for it to be considered at the moment. However, it certainly can be produced cheaply from natural gas, and therefore it is of considerable potential interest; it can also be produced from coke oven gas.

MR PLEETH : In Table II I have given the calorific value of methanol, among other fuels, and it is shown to be only 48 per cent of that of gasoline, whereas the calorific value of ethanol is 66 per cent. In a fuel it is necessary to use less methanol in order to keep the loss of B.Th.U. down to a reasonable figure, for otherwise consumption figures on road tests would be high. But I cannot see any particular advantage in using methanol rather than ethanol. I gather that Mr Claxton is suggesting the use of coke oven gas as a source of ethylene.

MR CLAXTON : Yes.

MR PLEETH : If ethylene is used it is far easier to produce ethanol than to produce methanol by the Fischer–Tropsch method or water gas synthesis using coal as a raw material. I cannot see any advantage in producing methanol rather than ethanol when every advantage which methanol possesses is also possessed by ethanol in even greater degree. It has a higher calorific value, and its solubility relationships are simple, whereas in the case of methanol they are very difficult indeed. I should like to see methanol used, but ethanol is a preferable fuel.

F. C. SHEFFIELD : There are some aspects of this question that might be considered from the angle of the motor manufacturing industry. The economic advantage of using a home-produced fuel instead of imported gasoline seems to be a matter for debate which it is hardly possible to go into here. There is, however, another factor. The British motor manufacturer has necessarily to produce a car engine to operate on a low octane fuel, and he can do that quite satisfactorily. Nevertheless, he has to sell his vehicles to countries in which high octane fuels are available. Thus he is placed in a quandary. There are enough compromises to be made in an engine without compromising with regard to the fuel.

Would Mr Pleeth recommend, or consider it desirable, that in the U.K. we should work to the end that all fuel sold normally at the pumps, and for which the manufacturer has to design his engine, should be an alcohol blend ? As shown in the paper, alcohol permits the use of a higher compression ratio, which will give a higher thermal efficiency, and that in turn will give a lower rate of fuel consumption—and lower fuel consumption is particularly important to-day. So again I ask, is it deemed desirable, as a matter of national policy, to propagate the idea that there should be alcohol-blended fuel for use in the U.K. ?

All these questions of economical operation are of vital importance when marketing vehicles, particularly commercial vehicles, which are not sold because they have a lot of chromium fittings, but solely on their performance. Big operators are very concerned about the intervals between maintenance and between renewals of components, such as cylinder liners, pistons, rings, bearings, and so on. There is a very disturbing factor which has come to my notice, and I should be glad if Mr Pleeth could say something about it. This is the result of a series of wear tests which has been made recently in the United States by Jackson and others, and it appeared in an SAE Preprint dated 30 September 1951. It deals with the use of radioactive tracer technique. On the question of fuels there is

the very positively worded sentence, "Definite increase in wear is caused by as little as 2 per cent of alcohol used in fuel blends." Is there accelerated wear due to the use of alcohol in those fuels?

MR PLEETH: As to wear tests, there is a book comprising several hundred pages on the subject of alcohol; I have been speaking for twenty minutes, and I left out reference to wear because I had to leave out something. I will look up the paper by Jackson in order to see its purport.

Before the war, however, some very controversial figures were presented concerning increased wear arising from alcohol blends, and I was drawn into the controversy. The man who had produced the figures was asked to rig up his identical test again and to use controlled methods. When the controlled methods were applied—I mean using fuels of identical sulphur content—he found no appreciable difference in wear. I do not think there is any difference in wear whatsoever as between the use of alcohol blends and gasoline so long as the sulphur content is maintained at the same figure.

MR OWTRAM: Putting Mr Sheffield's question concerning the effect of the fuels on the motor manufacturers in a more general way, it comes to this—is it advisable that something should be done at all costs whereby we can have a high octane fuel on the market? Of course, putting it in general terms, we could all agree on the answer. But we should bear in mind that the reasons why there are no high octane fuels on the market here—and I am not trying to say whether those reasons are good or bad—have something to do with our balance of payments. If the provision of such fuels by way of alcohol were to necessitate a lot of extra capital expenditure in order that the alcohol might be produced, it is quite possible that that, too, would be harmful and perhaps more so to the balance of payments. It is difficult to see how it could be sound to build additional plants for this purpose when newly-built modern plants already exist in the U.K. for the production of these fuels by other methods.

B. S. DUEGAN: We have heard some views in favour of the use of alcohol, but I have doubts about it and should like to ask a few questions.

The first concerns the corrosion of containers and tanks. These are generally rust-proofed by painting with gasoline-resistant paints, but these are dissolved by alcohol motor fuels and peel off. If alcohol motor fuels are adopted as normal motor fuel, these containers will have to be coated with materials that are resistant *both* to neat gasoline and alcohols. I would ask Mr Pleeth whether any material has since been developed and used that will resist attack by both fuels. This difficulty might possibly be overcome by plating the packs, but that would not be desirable in view of the world shortage of the plating materials and the high cost of plating.

The next point is that of the deterioration of the fuel pump diaphragms. These are resistant to neat gasoline, but when alcohol motor fuels are used the diaphragms are apt to dissolve and to spoil the fuels. Presumably this difficulty could be overcome by using synthetic rubber diaphragms. I would like to know what is actually being used in America, and on the Continent.

Thirdly, I would refer to the storage stability of alcohol motor fuels.

I think that Hixon and Fulmer storage stability tests, referred to by Mr Pleeth in his paper, were carried out on blends of maximum water tolerance. It is very likely that under high humidity conditions in tropical countries, alcohol motor fuels would separate into two layers, especially in the case of blends having border-line water tolerance. I am therefore very pessimistic regarding the future of these blends as normal motor fuel, apart from their use in certain countries purely for reasons of economy. I feel that engine manufacturers will be well advised not to start manufacturing engines of higher compression ratios on the assumption that alcohol motor fuels would meet their requirements, until such time that these fuels are made immune to water attack by means of suitable additives.

MR PLEETH : It is quite true that almost our first trouble, when alcohol blends were introduced, was that of the stripping of the shellac or other lacquer used inside fuel tanks. But I gather that the motor manufacturers no longer specify internally lacquered tanks and that that trouble no longer arises.

I have done a lot of work in connexion with gasoline-resisting paints and, so far as I am aware, no paints will resist alcohol blends indefinitely; eventually the paint inside tanks containing those blends will strip. But we have developed a number of paints, which can be sprayed on in the ordinary way, which will resist the dripping effect. We use such paints on our own lorries to resist the effects of the dripping of alcohol fuels six or eight times a day when loading takes place. They are resistant to alcohol-blended fuels in that respect.

The normal rubber pump diaphragm will definitely disintegrate in contact with alcohol blends. But the pump manufacturers have developed synthetic rubber diaphragms, and the life of diaphragms made of those new types of materials is as long when in contact with alcohol blends as when in contact with gasoline.

Hixon and Fulmer quote the use of a 10 per cent alcohol blend for all their tests. You speak of a marginal water tolerance. A 10 per cent blend has a certain water tolerance, which can be learned from the literature.

MR DUEGAN : My point is that one cannot specify the maximum water tolerance in specification for alcohol motor fuels. On the other hand, suitable minimum water tolerance has to be specified. If a blend is made of 100 per cent pure alcohol and absolutely water-free gasoline, this blend will be highly water tolerant, or in other words the water tolerance will be at the maximum. But it will be agreed that this is not practicable, as in practice alcohol is not 100 per cent pure and gasoline is not absolutely free from water. For example, a 20 : 80 ethyl alcohol : gasoline blend will have a maximum water tolerance of the order of 1·2 ml per 100 ml of the blend, if alcohol is 100 per cent pure and the gasoline is absolutely free from water. However, in specifications governing supply of this blend a minimum water tolerance of 0·9 ml per 100 ml of the blend is specified. The difficulty is particularly with the blends which are just on the border-line in respect of water tolerance. I consider that special precaution should be taken during handling of alcohol motor fuels to prevent ingress of moisture, namely (i) storage under cover and use of leak-tight containers, (ii) blend fuel in small

quantities for day-to-day requirements as far as possible, and (iii) minimize transport of blended fuel as far as possible. I feel there is a field open for the use of some suitable additive in the blend which will make it immune to water attack.

MR PLEETH: I think the speaker has the subject reversed. In fact, any given blend has a *maximum* water tolerance. The tolerances are published in the literature. If the composition of the blend is known—*e.g.*, 15 per cent alcohol, 8 per cent benzole, and the rest gasoline—the chart will show the maximum water tolerance of that blend. All our depot managers have these charts in their possession; when a blend is made they can determine by a very simple device the water tolerance of that blend, and can compare that water tolerance with the figure given on the charts. The figure given on the charts is the maximum possible, assuming there is no water in the alcohol, benzole, or gasoline to start with. If they arrive at a water tolerance appreciably below the figure given in the charts, the blend must be discarded. Out of the thousands of blends I have supervised, only two have separated at all. The water tolerance given for a blend is a maximum, not a minimum.

Suppose one is dealing with a blend containing 20 per cent of alcohol. The blender would know that the water tolerance should be 1·9 per cent. Suppose by means of the simple device I have mentioned he determines that it is only 0·4 per cent. He would then know that he has introduced 1·5 per cent of water into his blend, and that the blend is dangerous. Each man has instructions showing the maximum figure he should achieve under ideal conditions. He is not expected to achieve the ideal condition, but to keep reasonably near to it. If the figure is 1·9 per cent, he is allowed to go down to 1 per cent. If the figure as determined is below 1 per cent, the blend must not be sold. No one would sell a blend which, if one drop of water were added to it, would separate, for it is known that any fuel will at some stage come into contact with small quantities of water somewhere.

W. D. DAVIES: I would like to ask a question about new fuel systems and alcohol fuels. I believe that methanol and water injection has been used with some success in aircraft engines during take-off conditions. This system was later introduced to automotive engines by one of the large American manufacturers using a fuel system whereby a pump introduced methanol and water as the octane requirement of the engine increased. Has the author any ideas on this particular use of alcohols, as it may have some interesting application in future high compression automotive engines?

MR PLEETH: We have done some work in that direction, and I think someone in the United States has patented a device which gives a dual fuel system. The supply of the second fuel, a water–ethanol mixture, is connected to the induction intake of the carburettor, so that the higher the demand on the engine (and such demand would normally cause knocking), the greater the flow of the water–ethanol mixture into the fuel system.

I am fairly certain that that system will work very well indeed. But it would add one more complication to the already complicated motor car mechanism.

G. BARRETT: In his paper Mr Pleeth gives a table which includes thermal efficiencies, and the figures seem rather high. I presume that these are indicated thermal efficiencies.

MR PLEETH: Yes, I use theoretical percentages, because the theoretical figures can be obtained without the intervention of the variable of a motor car.

THE CHAIRMAN: I should like to make one comment about the road test *versus* bench test argument which seems still to be going on. Some twenty-five years ago, when I first came up against it, it was thought the problem was completely solved, because the CFR engine was just coming into use and there was a nice laboratory method which would give the answer. Although it was thought at that time that the problem was solved, it has been argued about ever since, and still presents a challenge to the technician, because if the two tests disagree there is something wrong with either the road test or with the bench test.

I am sure you will wish me to convey to the authors of both papers our thanks for the way in which they have presented their very interesting subject and have replied to the discussion. I ask you to accord them a very hearty vote of thanks.

(The vote of thanks was warmly accorded, and the authors briefly expressed their appreciation.)

J. H. RANDALL, in a written contribution, said: Mr Pleeth is to be congratulated on his excellent paper, in which he has presented the case for alcohol fuels based quite obviously on a large amount of practical experience of the problems involved in their use. He has succeeded in my view in bringing into proper perspective many of the technical objections that have been advanced from time to time against their use.

Mr Pleeth goes on to consider ways and means of providing increased quantities of suitable alcohols for fuel purposes. His suggestions regarding the production of ethanol and *iso*propanol from petroleum cracking operations seem reasonable and logical in this connexion, but I find it more difficult to accept his further suggestions in regard to the use of methanol. In my experience the introduction of methanol into a petrol–alcohol blend reduces the water tolerance to such a degree that the addition of other blending agents is almost essential. Ethyl alcohol, benzole, and butanol are examples of such agents, but the quantities required to give a reliable water tolerance standard are usually excessive except for special purposes.

I was disappointed in the paper in one respect, namely that Mr Pleeth has made no reference to the use of alcohol in conjunction with a bi-fuel system. There is nothing new in the basic idea associated with this system. I can remember carrying out a series of experiments in the early 1920s using this system in connexion with the development of alcohol fuels before anhydrous alcohol was commercially available. While little work has been done in the advancement of this technique in the meantime, the scheme came into prominence once again at the later stages of the last war in connexion with aircraft operation, and more intensive development has ensued since,

particularly in America, for automobile use. The principles underlying this system are well known, but it may be a convenience for this discussion to briefly restate them.

Most road vehicle I.C. engines operate for a very large proportion of their life at not more than half-throttle conditions; in other words at an effective compression ratio considerably below the designed ratio. On the other hand, the octane number of the fuel used has quite clearly to be suitable for those very rare occasions where the unit operates under nearly full or full load conditions. Thus it will be appreciated that such a fuel which is normally relatively expensive, is really unnecessary for a goodly proportion of running time, resulting in wasteful and unnecessarily expensive operation. This difficulty is inherent using a single fuel. The solution is, of course, evident, and it is to use a lower grade material as the main operational fuel and to supplement this with an anti-detonant fuel when load conditions make this necessary. This is exactly the objective of the bi-fuel scheme, and the idea is almost " tailor-made " for alcohol fuels.

Such things as the question of water tolerance, and the special precautions in storage or distribution need no longer be considered, and matters of blending agents and even suitable distillation ranges also disappear. The advantages of all this are too apparent to need detailing, and any vehicle fitted with the necessary equipment can use any of the suitable alcohols, either from choice or depending upon availability.

Laboratory and road testing of this scheme have shown it to be quite practical. Comparative experimentation using a normal alcohol blend as the straight fuel, and a 65 octane gasoline as the basic fuel, with ethyl alcohol as the anti-detonant, in conjunction with a bi-fuel scheme has shown that the same performance can be achieved with considerable economies. Savings of up to 50 per cent in the amounts of alcohol consumed have been demonstrated.

It may be objected that the additional accessories necessary to utilize this system, or having to fill up with two fuels, would be sufficient to prevent any large scale development. I wonder if this is so—in these days of upper cylinder lubricants, and fuel additives, multi-carburettor engines, reserve fuel tanks, and so on. Very little extra expense would be added to the cost of the vehicle to provide the fitments if they were included in the maker's specifications at the time of manufacture, and the order of this extra cost would, in the writer's view, be easily offset by the operational advantages. There is, of course, still a long way to go before the use of such a system could become standard practice, but it is suggested that it offers one of the most promising channels for development in the use of anti-detonants economically, giving advantages both to the manufacturers and the user alike.

Considerable work has been done on the use of direct injection for gasoline-driven I.C. engines. I have no knowledge whether similar experiments have been undertaken using gasoline–alcohol blends in the same way. It does seem, however, that such a method might offer some advantages, since it would seem to utilize one of the available characteristics of alcohol as a fuel, namely, its high latent heat in the right place, *i.e.*, in the cylinder and not in the carburettor and subsequent distribution system.

In reply to Mr Randall, MR PLEETH wrote : The addition of methanol to gasoline raises two problems : a reduction in calorific value and a reduced water tolerance. On both these grounds I should be unhappy to recommend its use except as a comparatively small percentage of the ethanol in the blend, and even then only when the cost is sufficiently low and the availability sufficiently high to justify the risk taken.

The bi-fuel device is an excellent one, and it may be found a standard fitting on all cars one day. The only drawback is that motorists will have to be supplied with a second fuel, with all the complex distribution problems involved, despite a sale of less than one-tenth that of the main fuel.

Thaler * has reported on direct injection systems for alcohol and has produced figures favourable to that fuel. Fabian † has stated that while a normal carburettor will give a volumetric efficiency of 90 per cent, direct injection into the cylinder will give an efficiency of 100 per cent. Undoubtedly direct injection has its advantages, but this must be weighed against the enormous increase in complexity of a number of injection pumps (*i.e.*, one per cylinder) compared with a carburettor (one per four or six cylinders).

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* Thaler, L. *Ann. des Mines et des Carb.*, 1944, **6**, 525–40.
† Fabian. *Tech. Mod.*, 1–15.6.48, pp. 195–7.

THE INSTITUTE OF PETROLEUM

An Ordinary General Meeting of the Institute of Petroleum was held at 26 Portland Place, London, W.1, on 26 March 1952, Mr E. J. Dunstan (Vice-President) in the Chair.

The Chairman, introducing the authors of the paper to be presented, said: It is refreshing in these days, when everybody is occupied in trying to produce or to change some natural product, to find that someone is working on materials of which no country has a monopoly. We are fortunate to have with us to-night Dr Hall, Dr Gall, and Mr Smith as co-workers on this problem at the Fuel Research Station. Dr Hall is also responsible for a lot of information which has come to us from the work carried out in Germany during the war.

Dr C. C. Hall then presented the following paper.

A COMPARISON OF THE FIXED-BED, LIQUID-PHASE ("SLURRY"), AND FLUIDIZED-BED TECHNIQUES IN THE FISCHER–TROPSCH SYNTHESIS

By C. C. Hall,* D. Gall,* and S. L. Smith *

Introduction

In common with most other heterogeneous catalytic gas reactions, the synthesis of hydrocarbons from carbon monoxide and hydrogen by the Fischer–Tropsch reaction was originally studied and developed in tubular reactors containing a static bed of catalyst granules through which the reacting gases were passed. As the reaction is highly exothermic and its selectivity dependent on rigid temperature control, tubes of small diameter surrounded by a cooling medium were necessary. On a commercial scale this externally cooled fixed-bed system possessed several disadvantages. With the cobalt catalyst used in the German plants in the period 1936 to 1945, it was impossible to increase the space velocity beyond about 100 volumes synthesis gas per volume catalyst per hour without losing temperature control and causing excessive production of methane and carbon. The output of a commercial reactor was therefore restricted to about 2 tons of hydrocarbon products per day. To replace spent catalyst, each reaction vessel in turn had to be taken off stream, cooled to room temperature, discharged, and then re-charged with fresh, reduced catalyst in an

* Fuel Research Station, DSIR.

inert atmosphere—a procedure requiring a team of skilled and experienced men.

There was no indication from German wartime research work that replacing the cobalt by iron catalysts removed these limitations of the fixed-bed system, although the cheapness and flexibility of iron catalysts has led to their almost universal adoption in process development work since about 1943.

A number of alternative process techniques were investigated in Germany with a view to overcoming the shortcomings of the fixed-bed method of operation. One of the most promising of these techniques was the liquid-suspension or " slurry " process, in which the reacting gases were passed through a dispersion of finely powdered catalyst in high-boiling oil. The catalyst was maintained in suspension either by the velocity of the gas stream, by mechanical agitation, or by circulation of the slurry through the reactor and through an external cooling system. This technique promised the advantages of comparative simplicity of reactor design, efficient cooling of the catalyst particles, and ease of catalyst replacement without interruption of the process. An important feature of the results obtained in German work on this process was the high selectivity (low methane formation) achieved. This is of particular importance where high-cost synthesis gas derived from coal is the raw material for the process. Space–time yields of products appreciably greater than those obtained in the fixed bed were claimed.

Wartime German work on this process has been summarized by Storch, Golumbic, and Anderson.[1] Work carried out in the laboratories of Gewerkschaft Rheinpreussen has been described by Kölbel and his co-workers,[2, 3] and recent U.S. Bureau of Mines work on this technique has been reported by Schlesinger, Crowell, Leva, and Storch.[4] According to Kölbel[3] this process possesses extraordinary flexibility with respect to type of catalyst, synthesis gas composition, range of permissible operating conditions, and composition of products.

The application to the Fischer–Tropsch process of the fluidized-catalyst technique, developed with such success for the catalytic cracking of petroleum oils, was investigated during the war years by the American oil companies. This work resulted in the development of the " Hydrocol " process, designed, primarily, for the production of high-grade petrol from natural gas.[1, 5, 6, 7] In this process a powdered iron catalyst is maintained in a fluidized state at a temperature of 320° to 350° C and pressures in the range 300 to 450 p.s.i.g., by an up-flowing stream of synthesis gas and recycled tail gas. The main product of the process is 80-octane petrol. The construction of an 8000 b.d. plant utilizing this process at Brownsville, Texas, was completed in 1950, but no report concerning its performance has yet been published. Experimental work on the use of fluidized iron catalysts in the Fischer–Tropsch process at the Fuel Research Station has been in progress since 1948.[8, 9]

The main advantages of this technique are the high space–time yields obtained (some twenty times greater than those obtained in the German commercial fixed-bed reactors) and the high quality of the petrol produced. To a large extent both these result from the use of high operating temperatures, although the high space–time yield is made possible in large-scale

operation by the high heat-transfer rates obtainable in fluidized–solid systems. The use of high temperatures, which is obligatory in order to avoid the production and condensation on the catalyst particles of high-boiling products, tends to favour carbon formation and consequent disintegration and volume-expansion of the catalyst. To minimize carbon formation, synthesis gas rich in hydrogen must be employed in this process. The combination of high temperature and hydrogen-rich gas leads to low selectivity (excessive methane production). It will be seen, therefore, that this process tends to be inflexible with respect to feed-gas composition and boiling range of products, and to sacrifice selectivity in order to achieve high space–time yields of high-grade petrol.

In previous work the nature of the catalyst, the composition of the feed gas, and the temperature and pressure used in the study of the various process techniques have differed considerably. Thus, in most fixed-bed and liquid-phase studies precipitated catalysts (pretreated in CO-containing gases, rather than reduced in hydrogen) have been used with water-gas or gases richer in CO than water-gas as feed material. Reaction temperatures have not normally exceeded 260° C, and the operating pressure has not exceeded 300 p.s.i.g. In the fluidized-bed process fused catalysts of the type used for ammonia synthesis or sintered preparations based on magnetite are the preferred catalysts. These are completely reduced in hydrogen and used with hydrogen-rich synthesis gas at temperatures above 300° C and pressures in the range 300 to 450 p.s.i.g.

Hence, in comparisons of the various process techniques, such as that made by Storch and his co-authors,[1] it is not possible to determine to what extent the results achieved by the use of a particular technique were due to the nature of the catalyst, the feed-gas composition, etc., employed and to what extent they were characteristic of the technique *per se*. In the work described in the present paper an attempt has been made to resolve this question by carrying out synthesis experiments in fixed-bed, liquid-phase, and fluidized-bed reactors under identical conditions of catalyst, temperature, pressure, gas composition and throughput, and recycle ratio.

Although it is possible to compare performance in the fixed-bed and liquid-phase systems under a variety of conditions, owing to the limitations of the fluid-bed system a comparison of all three techniques could be made only within the narrow range of conditions in which the fluid-bed process is operable. Thus, the use of hydrogen-rich gas and temperatures of at least 300° C were essential conditions. Furthermore, owing to the necessity in the fluid-bed system of using linear gas velocities sufficiently high to maintain the fluidized state, a high fresh feed-gas rate is necessary if very deep beds or excessively high recycle ratios are to be avoided. To effect the desired comparison, therefore, it was necessary to attempt operation of the fixed-bed and liquid-phase processes under conditions hitherto regarded as unsuitable for these systems. Previous work at the Fuel Research Station [8] had suggested, however, that it was possible to operate a laboratory-scale fixed-bed reactor at temperatures in the range 300° to 330° C and synthesis gas rates of 1000 vol/vol catalyst/hour without loss of temperature control or "plugging" of the catalyst bed by carbon formation.

Account of the Experiments

All experiments were carried out in synthesis units of similar capacity and general arrangement.

For fixed-bed operation, the reaction vessel was a thick-walled steel tube, 10 mm I.D., embedded in an electrically heated aluminium block, 6 cm diameter, and suitable for a catalyst charge of 20 to 80 ml. The general arrangement of the apparatus is shown in Fig 1.

Liquid-phase experiments were carried out in an electrically heated steel tube, 5 cm I.D. and 120 cm long, normally operated with a charge of 500 to 1500 ml of slurry containing 200 to 500 g catalyst per litre. In this unit preheated synthesis plus recycle gas passes up through the slurry at

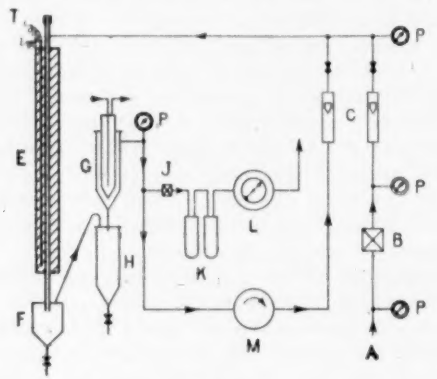

Fig 1

APPARATUS USED FOR FIXED CATALYST-BED EXPERIMENTS

a rate not less than that required to maintain the catalyst in uniform suspension. (For the fused-iron catalyst used in the experiments, this minimum rate was found to be 50 litres per hour at reaction temperature and pressure.) Volatile products leave the reactor overhead, while non-volatile products remain in the slurry. The liquid level in the reactor is located by temperature exploration. The temperature is uniform within the zone occupied by the slurry, but falls sharply at the gas/liquid interface. The liquid level is maintained constant either by withdrawing liquid medium via a filter immersed in the slurry or by returning heavy oil and wax from the partial-condenser receiver. Any liquid withdrawn from the reactor for level-control purposes during a test period is included in the product yield for that period. The arrangement is shown in the diagram, Fig 2, and in the photograph, Fig 3. Other conditions being constant, the results obtained in this reactor were found to be independent of the depth of slurry over the range studied (20 to 80 cm).

For experiments with fluidized catalysts, a reactor 14·4 mm I.D. by 244 cm long, embedded in an electrically heated aluminium block, 6·5 cm diameter was employed. A column of 1·5-mm steel balls in the lower 30 cm of the reaction tube served as the catalyst support and gas distributor,

and a centrally placed 16 gauge nichrome wire, carrying cross pieces made from 2·4 × 0·8 mm brass strip at intervals of 2·5 cm, acted as a "slug breaker." Tests in glass models showed that smooth fluidization could be obtained in beds of catalyst 14 mm diameter and 60 cm deep. A flow diagram of the apparatus is shown in Fig 4, and the general arrangement in the photograph, Fig 5. Certain of the experiments were carried out in the 25 mm × 2·1 m reactor previously described.[9] For all experiments,

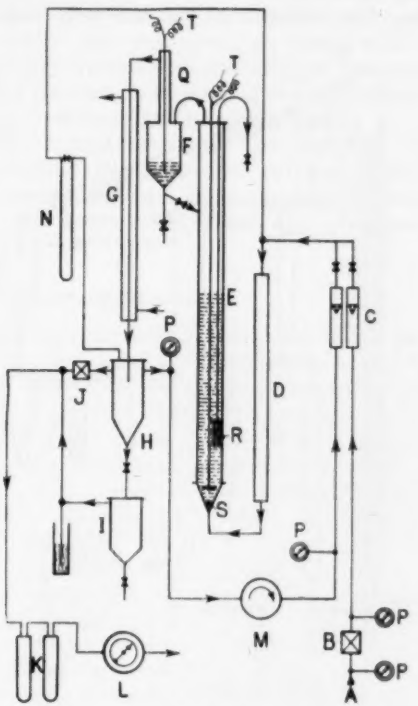

FIG 2

APPARATUS USED FOR LIQUID PHASE (OIL/CATALYST SLURRY) EXPERIMENTS

synthesis gas containing 93 to 95 per cent of hydrogen and carbon monoxide in the proportions 2 : 1, and not more than 0·1 g total sulphur/100 m^3 was employed as the raw material.

Two catalysts were used, viz., a commercial ammonia-synthesis catalyst prepared by fusion and containing 3·4 per cent MgO and 0·7 per cent K_2O as activators, and a sintered catalyst, prepared from mill scale, containing 1·5 per cent K_2O as activator.[9] For the liquid-phase technique results are available only for the ammonia-synthesis catalyst.

Except where otherwise indicated, granules 7 to 14 British Standard sieve sizes were employed for the fixed-bed tests and a powder of size range 72 to 170 BSS, for the fluid-bed experiments. The particle size of

the catalyst used in the slurry experiments is not known accurately, but was less than 200 BSS.

In each case the catalyst was completely reduced before synthesis by treatment with pure hydrogen for 24 hr at 450° C and an hourly space velocity of 1000. In the fixed- and fluidized-bed experiments the reduction was carried out in the synthesis reactor. For the liquid-phase experiments the catalyst was reduced in the form of 7 to 14 BSS granules in a separate vessel, transferred in an atmosphere of CO_2 to an air-tight ball mill and ground for 24 hr. The contents of the mill were then washed out with

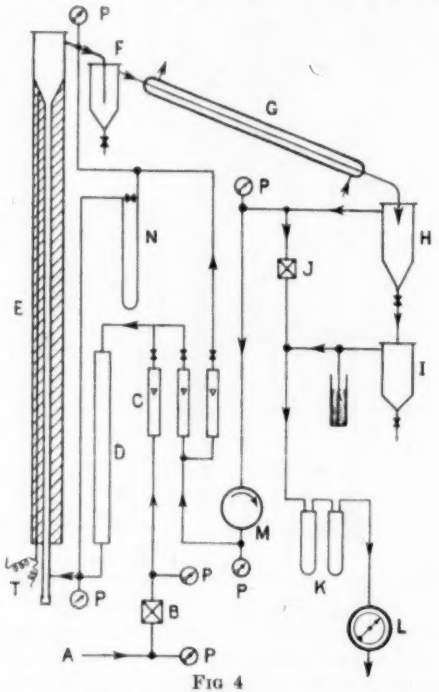

FIG 4

APPARATUS USED FOR FLUID-CATALYST EXPERIMENTS

Fischer–Tropsch diesel oil and transferred to the reactor which contained molten wax maintained at 120° C and agitated by a slow stream of hydrogen. The wax used as the slurry medium was a refined, Fischer–Tropsch hard paraffin, melting point 90° C.

In all three plants the major portion of the liquid product was recovered by cooling the effluent gas stream from the reactor to room temperature and the remainder by condensation in traps cooled to −80° C in dry ice. In all cases a portion of the gas stream was recycled to the reactor inlet after cooling to room temperature but before refrigeration. Over each successive period of 24 hr operation the volume of synthesis gas passed and of tail gas bled off was determined, the weight of liquid products measured and average samples of residual and synthesis gases analysed.

The yield of C_{5+} hydrocarbons was determined by direct measurement, and the CO and CO + H_2 conversions, H_2/CO usage ratio, and yields of methane and C_2 to C_4 hydrocarbons calculated from the gas analyses and the overall gas contraction.

Analysis of the liquid products was carried out only to the extent necessary to indicate major changes in boiling range (by modified Engler distillation) and in unsaturation, alcohol, acid, and ester contents (by determination of bromine, hydroxyl, acid, and ester numbers of the 80° to 150° C fraction). The acids present in the reaction water were determined by titration and calculated as acetic acid, and the neutral organic matter (mainly alcohols) by saturation of the water with potassium carbonate, followed by ether extraction of the organic matter and removal of the ether using an efficient fractionating column.

Data for carbon formation during the synthesis were obtained by exhaustively extracting the recovered catalyst with benzene and/or toluene and determining the total carbon present by combustion analysis. In selected cases the spent catalyst was also analysed for carbide and oxide.

Comparison Experiments at 300 *p.s.i.g.*

Prior to the work reported later in this paper, synthesis experiments had been restricted to a maximum operating pressure of 300 p.s.i.g., and the initial comparison tests with the three process techniques were made at this pressure. Most previous fixed-bed tests had been carried out at a temperature of 265° C, at which temperature a CO conversion of *circa* 95 per cent could be maintained for several weeks at a space velocity of 400 vol synthesis gas/vol catalyst/hr (0·20 to 0·25 litres synthesis gas/g reduced catalyst/hr). Results for operation with the two catalysts in the fixed bed and for the ammonia-synthesis catalyst in the slurry reactor under such conditions are recorded in Table I.

Attempts were made to operate the fixed-bed reactor at 300° C and an hourly synthesis-gas space velocity of 1000. In the case of the ammonia-synthesis catalyst a period of ten days' operation under these conditions (following a period of seventeen days' operation at 265° C and a low space velocity) was achieved before a blockage developed in the reactor, but with the mill-scale catalyst the reactor plugged after only four days' operation. This was due to the greater rate of carbon formation on the latter catalyst.[9] The results obtained in these two trials are given in Table I.

For the slurry process, results are shown in Table I for operation at 300° C and the maximum gas rate at which a 93 to 96 per cent CO conversion could be maintained. Results of runs in the fluid-bed unit with both types of catalyst and with a catalyst extensively diluted with carbon in a previous experiment are also recorded in Table I.

Effect of Operating Pressure

German work with precipitated catalysts showed that the synthesis rate increases linearly with pressure up to 225 p.s.i.g.,[10] and the U.S. Bureau of Mines have more recently confirmed this relation for fused and sintered catalysts when using water-gas as raw material.[11] In the present

TABLE I

Conditions Used and Results Obtained at 300 p.s.i.g. in Fixed-bed, Liquid-phase, and Fluidized-bed Operation.

A.S. = Ammonia-synthesis catalyst M.S. = Mill-scale catalyst
M.S.(A) = M.S. catalyst of bulk density 0·23 g/ml, containing 47·5 per cent of carbon resulting from a previous synthesis run

1. Reaction system	Fixed bed					Liquid phase					Fluidized bed				
2. Experiment number	12/54	12/54	12/51	12/53	12/63	17/10	17/10	17/10A	17/10A	17/10A	16/12	19/17	16/16	16/14	16/19
3. Catalyst	A.S.	A.S.	M.S.	M.S.	A.S.	A.S.	A.S.	A.S.	A.S.	A.S.	A.S.	A.S.	M.S.	M.S.	M.S.(A)
4. Mesh size, BSS	7–14	7–14	7–14	7–14	25–36	<200	<200	<200	<200	<200	72–170	72–170	72–170	72–170	72–170
5. Concentration, g/litre reaction space	2073	2073	1590	1580	2075	470	940	310	155	220	*ca* 1000	*ca* 1000	*ca* 1000	*ca* 1000	*ca* 115
Operating conditions															
6. Pressure, p.s.i.g.	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
7. Temperature, °C	265	300	265	300	265	265	265	265	265	300	305	305	305	305	312
8. Synthesis gas, H_2 : CO ratio	2·02	2·00	2·10	2·07	2·05	2·05	2·05	2·04	2·10	2·04	2·00	1·96	2·08	2·02	2·12
9. Throughput, vol/vol catalyst/hr	427	1087	380	1045	1235	—	—	—	—	—	1000	4400	1840	9100	1780
10. Throughput, vol/vol reaction space/hr	427	1087	380	1045	1235	110	220	98	98	196	500	2200	920	4600	890
11. Throughput, l/g catalyst/hr	0·21	0·53	0·24	0·65	0·60	0·24	0·24	0·32	0·64	0·89	0·58	2·24	0·96	4·90	7·22
12. Recycle ratio, vol recycle gas/vol synthesis gas	2	2	2·3	4	2·8	2·0	2·0	2·5	2·5	2·0	5·0	10·5	13·5	6·0	13·5
13. Total reactor feed H_2 : CO ratio	3·03	3·00	3·53	3·46	3·15	3·54	2·44	3·68	3·78	3·43	3·00	2·94	3·68	3·13	3·68
14. Hydrogen partial pressure, p.s.i.g.	136	129	149	104	128	158	184	155	175	147	69	83	106	179	106
15. Duration of test, hr	96	240	216	90	72	360	72	240	120	96	120	48	144	72	216
Gas conversions															
16. CO, per cent	94·3	95·3	94·2	96·1	93·5	94·2	66·2	92·4	86·9	94·1	98·1	95·3	96·2	67·6	95·5
17. CO + H_2, per cent	89·2	89·2	86·7	92·2	88·0	84·1	59·2	79·8	66·6	84·2	96·0	93·0	94·0	52·5	94·6
18. CO, l/100 g catalyst/hr	6·01	15·9	6·95	19·3	17·4	7·0	4·7	9·2	17·2	26·0	17·7	66·3	28·7	102·7	213·5
19. CO + H_2, l/100 g catalyst/hr	17·20	44·7	20·0	57·0	50·4	19·0	12·8	24·1	40·6	70·6	52·0	192·0	86·2	240·0	662·5
20. Usage ratio, H_2 : CO	1·86	1·81	1·87	1·95	1·90	1·72	1·73	1·62	1·40	1·72	1·94	1·89	2·01	1·34	2·10
Yields of products															
21. C_1, g/m³ synthesis gas	33·0	37·5	20·2	28·4	37·3	18·1	15·2	14·6	11·5	22·6	48·9	35·0	27·3	8·9	28·7
22. C_2–C_4, g/m³ synthesis gas	48·1	56·9	53·2	59·9	57·9	59·4	50·0	57·9	48·6	63·3	64·0	64·0	56·6	63·1	56·0
23. C_{5+}, g/m³ synthesis gas	80·3	75·0	83·0	94·8	72·6	78·9	40·0	80·0	71·0	78·8	66·4	69·4	87·9	40·7	90·4
24. Aqueous alcohols, g/m³ synthesis gas	3·2	2·1	9·7	5·5	1·8	12·4	—	13·8	8·0	9·5	4·2	5·7	9·0	4·5	9·9
25. Aqueous acids, g/m³ synthesis gas	1·3	1·9	7·1	5·0	1·6	2·9	—	2·3	1·6	1·6	0·9	1·6	7·6	3·9	4·0
Carbon formation															
26. g/100 g catalyst/day	—	—	—	—	—	—	—	—	—	0·28	4·8	—	5·0	—	5·2
27. g/m³ CO converted	—	—	—	—	—	—	—	—	—	0·45	11·3	—	7·3	—	1·0
Boiling range of C_{5+} product															
28. Below 200° C, per cent by wt	65·8	73·2	53·7	69·2	76·9	71·6	65·1	57·2	44·6	73·7	88·2	69·6	65·1	68·2	69·1
29. 200°–300° C, per cent by wt	20·4	14·0	18·9	15·4	14·4	15·0	14·0	23·1	21·1	16·8	9·1	18·9	20·7	18·3	17·9
30. Over 300° C, per cent by wt	13·8	12·8	27·4	15·4	8·7	13·4	20·9	19·7	34·3	9·5	2·7	11·5	14·2	13·6	13·0
Analysis of 80°–150° C fraction															
31. Olefin content, per cent by wt	51·2	68·4	61·4	60·8	49·1	62·3	59·8	61·3	59·0	64·5	82·2	64·5	66·5	60·5	71·3
32. OH No. mg KOH/g	42·6	52·8	22·7	84·7	63·0	87·0	66·9	122·7	122·5	52·2	14·9	28·0	27·1	34·2	49·8
33. Acid No. mg KOH/g	4·1	7·6	17·7	22·8	5·2	12·9	14·7	9·5	8·4	5·3	0·9	10·3	0·3	32·8	10·9
34. Ester No. mg KOH/g	4·3	11·5	9·1	31·3	0·9	5·4	8·2	1·5	1·8	3·8	nil	1·1	0·5	42·8	0·5

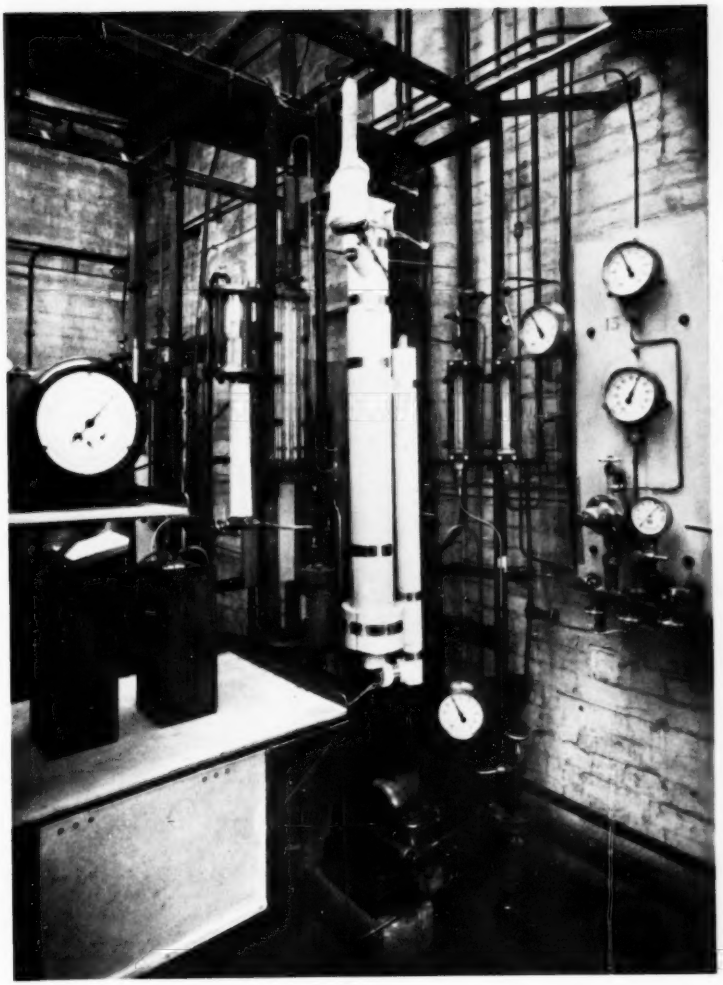

FIG 3

APPARATUS USED FOR SYNTHESIS IN THE LIQUID PHASE

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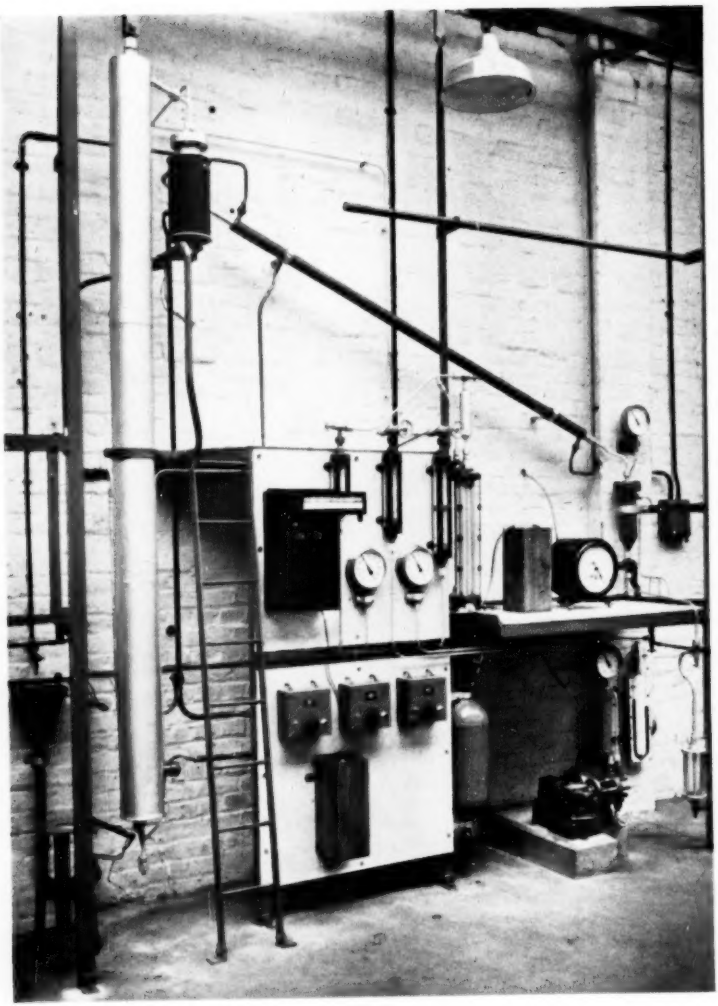

FIG. 5

APPARATUS USED FOR SYNTHESIS WITH FLUIDIZED CATALYST

TABLE II

Results Showing the Effect of Pressure in Fixed-bed, Liquid-phase, and Fluidized-bed Operation

A.S. = Ammonia-synthesis catalyst
M.S. = Mill-scale catalyst
U.M.S. = Unimpregnated mill scale

1. Reaction system	Fixed bed					Liquid phase			Fluid bed	
2. Experiment number	12/56			12/57		17/11			18/24	18/26
3. Catalyst	M.S.	M.S.	M.S.	A.S.	A.S.	A.S.	A.S.	A.S.	U.M.S.	U.M.S.
4. Mesh size, BSS	7–14	7–14	7–14	7–14	7–14	<200	<200	<200	72–170	72–170
5. Concentration, g/litre reaction space	1610	1610	1610	2090	2090	210	210	210	*ca* 1000	*ca* 1000
Operating conditions										
6. Pressure, p.s.i.g	300	450	600	300	600	300	450	600	300	600
7. Temperature, °C	250	250	250	250	250	265	265	265	320	320
8. Synthesis gas, H_2 : CO ratio	2·02	2·03	2·04	2·09	2·09	1·85	2·01	1·97	2·11	2·11
9. Throughput, vol/vol catalyst/hr	430	643	824	427	821	—	—	—	1760	3600
10. Throughput, vol/vol reaction space/hr	430	643	824	427	821	165	243	335	900	1800
11. Throughput, l/g catalyst/hr	0·27	0·40	0·51	0·20	0·39	0·78	1·15	1·59	0·91	1·86
12. Recycle ratio, vol recycle gas/vol synthesis gas	2·5	2·2	2·3	2·3	2·3	6·0	5·2	5·5	13	13
15. Duration of test, hr	144	96	96	96	96	144	96	96	144	120
Gas conversions										
16. CO, per cent	86·2	87·7	87·5	93·5	93·5	88·8	87·3	83·4	90·7	91·6
17. CO + H_2, per cent	73·5	76·0	79·7	82·1	84·8	75·9	74·7	69·6	91·8	92·4
18. CO, l/100 g catalyst/hr	7·03	10·73	13·85	5·90	11·40	21·5	31·0	41·1	25·6	52·8
19. CO + H_2, l/100 g catalyst/hr	18·00	28·30	38·48	16·48	32·80	52·2	79·6	102·0	80·7	165·5
20. Usage ratio, H_2 : CO	1·56	1·63	1·78	1·79	1·88	1·43	1·57	1·48	2·15	2·14
Yields of products										
21. C_1, g/m³ synthesis gas	19·0	19·3	15·1	29·0	24·5	18·2	14·9	12·7	62·4	61·5
22. C_3–C_4, g/m³ synthesis gas	34·0	49·8	57·7	46·0	52·0	38·5	36·9	37·0	58·8	55·8
23. C_5+, g/m³ synthesis gas	85·8	80·8	81·5	90·5	93·6	96·0	91·0	86·0	38·3	47·1
24. Aqueous alcohols, g/m³ synthesis gas	4·1	3·5	3·2	—	—	10·5	9·7	7·3	—	—
25. Aqueous acids, g/m³ synthesis gas	6·8	6·4	6·8	—	—	2·1	2·8	4·3	—	—
Boiling range of C_5+ product										
28. Below 200° C, per cent by wt	47·4	52·2	56·0	61·5	52·7	51·2	49·6	46·9	—	—
29. 200°–300° C, per cent by wt	26·2	26·7	23·1	19·7	25·1	15·0	15·5	15·6	—	—
30. Over 300° C, per cent by wt	26·4	21·1	20·9	18·8	22·2	33·8	34·9	37·5	—	—
Analysis of 80°–150° C fraction										
31. Olefin content, per cent by wt	52·5	45·3	43·5	43·7	42·1	72·0	62·8	50·6	—	—
32. OH No. mg KOH/g	133·5	125·0	136·0	41·0	48·0	70·0	95·9	143·0	—	—
33. Acid No. mg KOH/g	25·5	21·2	20·7	3·9	3·9	7·7	14·1	23·0	—	—
34. Ester No. mg KOH/g	38·9	11·4	10·2	6·5	1·1	16·8	20·9	37·3	—	—

work the effect of pressure over the range 300 to 675 p.s.i.g. has been explored. In the slurry reactor tests were made at 300, 375, 450, 525, 600 and 675 p.s.i.g. at a temperature of 265° C. A gas rate was chosen to give a CO conversion of between 85 and 90 per cent at the lowest pressure, and was then increased as the pressure was raised so as to maintain a constant time of contact. In Fig 6 the data obtained for the litres $CO + H_2$ converted per 100 g catalyst per hour are plotted against absolute pressure, and full data for the tests at 300, 450, and 600 p.s.i.g. are given in Table II.

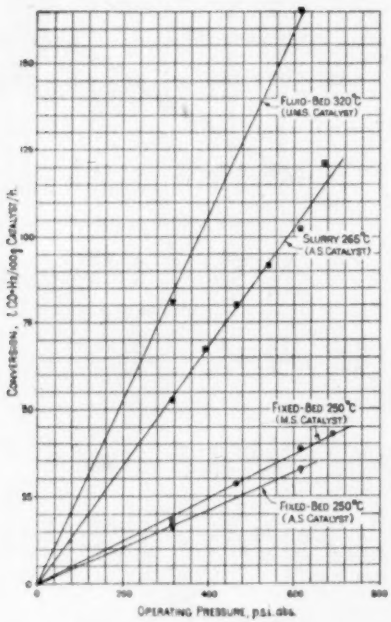

FIG 6

VARIATION IN CONVERSION RATE WITH OPERATING PRESSURE

Similar experiments were carried out in the fixed-bed reactor with the mill-scale catalyst at 300, 450, 600, and 675 p.s.i.g. and with the ammonia-synthesis catalyst at 300 and 600 p.s.i.g., in both cases at a temperature of 250° C. The results are shown in Fig 6 and Table II.

It is clear that the effect of an increase in working pressure can be assessed only at a temperature and throughput where the reaction rate is sensitive to variation in throughput at constant pressure. With the active catalysts employed in this work, this condition would be met only in the fluid-catalyst reactor by using an excessively high throughput. An indication of the effect of pressure in this system was therefore obtained by using as catalyst mill scale containing no added promotor. This material was much less active than the normal catalysts, and the conversion rate was sensitive to changes in throughput at the basic operating conditions of

temperature, 320° C, pressure 300 p.s.i.g., and space velocity 2000 vol/vol settled catalyst/hr. The results obtained at 300 and 600 p.s.i.g. are shown in Fig 6 and Table II.

Comparison Experiments at 600 p.s.i.g.

It was found that at 600 p.s.i.g. experiments could be carried out in the fixed-bed reactor at temperatures of 300° to 315° C and space velocities

TABLE III

Conditions Used and Results Obtained at 600 p.s.i.g. in Fixed-bed, Liquid-phase, and Fluidized-bed Operation

A.S. = Ammonia-synthesis catalyst
M.S. = Mill-scale catalyst
A.S.(B) = Ammonia-synthesis catalyst, bulk density 1·22 g/ml, carbon content 14·9 per cent resulting from previous synthesis operation.

1. Reaction system	Fixed bed				Liquid phase		Fluidized bed	
2. Experiment number	12/57	12/58	12/59	12/63	17/12	17/13	18/31	18/34
3. Catalyst	A.S.	A.S.	M.S.	A.S.	A.S.	A.S.	A.S.	A.S.(B)
4. Mesh size, BSS	7–14	7–14	7–14	25–36	<200	<200	72–170	72–170
5. Concentration, g/litre reaction space	2070	2070	1560	2070	210	405	ca 1000	610
Operating conditions								
6. Pressure, p.s.i.g.	600	600	600	600	600	600	600	600
7. Temperature, °C	305	315	305	305	295–320	305	305	305
8. Synthesis gas, H_2 : CO ratio	2·09	1·97	2·06	2·02	1·84	2·00	2·01	2·05
9. Throughput, vol/vol catalyst/hr	2110	3040	3070	7100	—	—	3260	2800
10. Throughput, vol/vol reaction space/hr	2110	3040	3070	7100	477	516	1630	1400
11. Throughput, l/g catalyst/hr	1·02	1·47	1·97	3·42	2·27	1·27	1·68	2·30
12. Recycle ratio, vol recycle gas/vol synthesis gas	2·3	2·4	2·4	2·0	3·7	3·7	13·3	2·0
13. Total reactor feed, H_2 : CO ratio	3·17	3·19	3·47	3·00	2·77	3·27	2·7	3·02
14. Hydrogen partial pressure, p.s.i.g.	281	256	273	266	241	228	100	199
15. Duration of test	144	144	144	96	168	192	144	240
Gas conversions								
16. CO, per cent	94·0	95·8	96·3	95·3	94·9	96·2	97·9	99·5
17. CO + H_2, per cent	88·0	90·9	90·5	90·1	93·0	93·5	97·0	96·7
18. CO, l/100 g catalyst/hr	29·7	43·6	58·7	101·0	61·8	37·9	50·9	70·9
19. CO + H_2, l/100 g catalyst/hr	86·2	122·4	169·0	288·0	171·8	110·0	152·3	210·0
20. Usage ratio, H_2 : CO	1·90	1·81	1·88	1·85	1·78	1·91	1·99	1·96
Yields of products								
21. C_1, g/m³ synthesis gas	27·0	30·4	22·4	30·1	20·5	24·5	36·7	31·7
22. C_2–C_4, g/m³ synthesis gas	65·0	58·0	56·9	63·4	52·0	53·2	80·2	88·5
23. C_{5+}, g/m³ synthesis gas	82·0	90·0	91·9	78·8	94·7	91·4	75·1	64·2
24. Aqueous alcohols, g/m³ synthesis gas	5·3	4·1	6·1	3·8	11·9	14·8	2·0	5·3
25. Aqueous acids, g/m³ synthesis gas	6·7	6·9	8·1	6·0	3·8	5·9	0·8	1·0
Carbon formation								
26. g/100 g catalyst/day	0·48	0·79	2·10	1·01	0·82	0·48	5·50	0·40
27. g/m³ CO converted	0·68	0·76	1·49	0·42	0·55	0·33	4·50	0·24
Boiling range of C_{5+} product								
28. Below 200° C, per cent by wt	73·0	73·1	62·3	76·1	64·3	79·8	80·6	81·6
29. 200°–300° C, per cent by wt	16·1	15·7	25·1	16·2	16·9	13·1	11·7	11·4
30. Over 300° C, per cent by wt	10·9	11·2	12·6	7·7	18·8	7·1	7·7	7·0
Analysis of 80°–150° C fraction								
31. Olefin content, per cent by wt	52·2	55·2	49·8	58·0	70·1	66·5	75·0	68·1
32. OH No. mg KOH/g	106·0	84·0	100·0	58·0	72·0	88·0	14·0	38·0
33. Acid No. mg KOH/g	20·8	21·2	26·8	18·8	14·4	11·1	2·0	4·0
34. Ester No. mg KOH/g	4·9	4·3	7·4	3·3	6·5	4·9	3·0	2·4
Analysis of used catalyst								
35. Iron oxide (Fe_3O_4), per cent by wt	68·5	72·5	—	65·2	—	45·3	5·8	34·8
36. Iron carbide (Fe_2C), per cent by wt	23·1	17·1	—	22·8	—	42·3	63·4	42·9
37. Free carbon, per cent by wt	0·5	2·8	—	4·4	—	4·4	18·4	15·1
38. Promoters, etc., per cent by wt	7·9	7·6	—	7·6	—	8·0	7·4	7·2

of 3000 vol fresh synthesis gas/vol catalyst/hr without plugging the reactor, thus facilitating comparison with experiments in the fluidized-catalyst reactor. The results of experiments with the two catalysts are recorded in Table III.

In the slurry process, by operation at 600 p.s.i.g., it was possible to maintain a 95 per cent CO conversion at hourly space-velocities of 500 (based on the volume of slurry under working conditions) by using temperatures in the region of 300° C. With a slurry containing 210 g catalyst per litre, a continual increase in temperature from 295° to 320° C over a period of seven days was necessary to maintain conversion, but with a more concentrated slurry, no increase in temperature was required over a period of eight days. The results of these two tests are shown in Table III.

The results of experiments in the fluid-catalyst reactor at 600 p.s.i.g. are also shown in Table III.

Normally, in order to maintain a linear velocity of 0·6 ft/sec under working conditions in the fluid-bed reactor and to avoid using either an unsuitably high fresh-gas rate or a very deep bed of catalyst, a high recycle ratio has been employed (*e.g.*, 13 : 1, as in Expt 18/31). In Expt 18/34, however, a carbon-containing catalyst of approximately half the bulk density of fresh catalyst (produced by a short period of synthesis under carbon-forming conditions) was used. This could be satisfactorily fluidized at 0·3 ft/sec with a relatively small bed expansion, and it was therefore possible to increase the volume of catalyst and to reduce the recycle ratio to the level used in the fixed-bed and liquid-phase experiments.

The Effect of Catalyst Particle Size

An obvious point of difference between the fixed-bed technique and the liquid-phase and fluid-bed techniques is the much greater size of the catalyst particles which must of necessity be employed in a fixed-bed reactor. With precipitated cobalt and iron catalysts, which possess a large internal surface with pores of large diameter, change in particle size (*i.e.*, external, geometric area) has little effect on the activity of the catalyst, but the U.S. Bureau of Mines has recently reported [11] that with fused and sintered iron catalysts the activity for synthesis in fixed-bed tests increases markedly with decrease in the size of granule. The data indicate, for example, that by reducing the mean particle size from 10 to 30 mesh, the activity is increased by 72 per cent. The rate of increase in activity, however, falls off with further reduction in size, and from 30 to 50 mesh is only 20 per cent. Although, therefore, it was not to be anticipated that the extremely small particles used in the fluidized and slurry systems would possess an activity greater than the granules used in the fixed bed in direct proportion to their smaller size, it was clearly of importance to determine the magnitude of the particle-size effect under the conditions employed in the present investigations.

In Table I the results of a fixed bed experiment are recorded in which 25/36 BSS granules of ammonia-synthesis catalyst were used for synthesis at 265° C and 300 p.s.i.g. with tail-gas recirculation, and it will be seen that the activity (in terms of litres CO + H_2 converted/100 g catalyst/hr) was very nearly three times as great as that of the 7/14 granules under almost

identical operating conditions and level of conversion. By operating with the same catalyst at a pressure of 600 p.s.i.g., a CO conversion of 95 per cent could be obtained at 305° C with a space velocity of 7000 vol synthesis gas/vol reaction space/hr. The results of this experiment (No. 12/63), which are recorded in Table III, indicate that at the higher temperature a reduction in particle size from 7–14 to 25–36 BSS increases the catalyst activity by a factor of 3·3. Finally it was found possible to determine in the fixed bed the activity of the 72–170 BSS particles used in the fluid bed. At 300 p.s.i.g. and 265° C and at 600 p.s.i.g. and 300° C the activity was 1·5 times greater than that of the 25–36 BSS granules or about 4·5 times greater than that of the normal 7–14 BSS granules. Thus, at the higher temperature and pressure, a conversion of over 96 per cent could be obtained at a space velocity of 10,000 vol/vol/hr giving an activity figure of 420 litres CO + H_2 converted/100 g catalyst/hr.

Discussion of Results

The results obtained by the three process techniques are discussed below under appropriate sub-headings.

The Effect of Operating Pressure

The results given in Table II and Fig 6 show that for fused ammonia-synthesis catalyst and sintered mill-scale catalysts and hydrogen-rich gas ($H_2/CO = 2$) the rate of the synthesis reaction is a linear function of pressure in the range 300 to 675 p.s.i.g. and that this relation probably extends to much higher pressures. Although the pressure range was explored in detail only in the case of the liquid-phase technique, it is evident that the relation holds equally for all three process techniques. In liquid-phase operation the results showed that increase in pressure at constant time of contact causes a slight fall in methane production but comparatively little change in usage ratio or in the boiling range of the liquid products. The olefin content of the spirit fraction falls and the alcohol, acid, and ester contents increase consistently with increase in pressure. With the same catalyst in the fixed bed somewhat similar effects are observed, but with the mill-scale catalyst, the fall in methane formation is not consistent, and the boiling range of the products changes towards an increased proportion of low-boiling compounds with increased pressure. Change in olefin content is less marked, and no consistent change in the content of oxygenated compounds is observed. Increase in pressure causes a significant rise in usage ratio. The results obtained in the fluidized reactor with unpromoted mill-scale catalyst are of interest only in showing the effect of pressure on reaction rate.

Catalyst Activity and Space–time Yield

The catalyst activity in these tests is considered in terms of the litres of CO + H_2 converted per 100 g catalyst per hour, and the space–time yield in terms of the litres CO + H_2 converted per 100 ml reaction space per hour, while maintaining *circa* 95 per cent CO conversion at a given temperature and pressure. The space–time yield is derived, therefore,

from the activity and the concentration of catalyst in g/ml of reaction space. In the fixed-bed process the catalyst concentration is given by the bulk density of the catalyst, and is thus constant for a particular catalyst, but in the slurry process it can be varied at will (within limits), and in the fluid bed the concentration will depend on the degree of expansion of the bed during fluidization and the fall in bulk density brought about by carbon formation. In the fixed bed, therefore, the gas rate in litres/g catalyst/hr bears a constant relationship to the space velocity in litres/litre reaction space/hr, *i.e.*, to the time of contact. In the other cases this is not so, and it can be shown that the variable which exerts the greater control over conversion level and activity is the space velocity. Thus in the two sets of results obtained for the slurry process in Expt 17/10 (Table I), the gas feed rate, in litres/g catalyst/hr, was the same, but the space velocity, which was varied with the catalyst concentration, was twice as great in one case as in the other. It will be noted that increasing the space velocity from 110 to 220/hr caused the CO conversion to fall from 94 to 66 per cent and the litres $CO + H_2$ converted/100 g catalyst/hr from 19 to 12·8. In Expt 17/10 A, however, in which a catalyst concentration of only 155 g/litre was employed at a space velocity of 98/hr, the CO conversion was 86·9 per cent and the activity in litres $CO + H_2$ converted/100 g catalyst/hr was 40·6, despite the fact that the gas rate in litres/g catalyst/hr was 2·7 times greater than in the above two tests in Expt 17/10.

In Expt 16/19 in the fluid-bed reactor, a carbon-diluted catalyst of low bulk density was used at a space-velocity of 890/hr and a rate of 7·2 litres synthesis gas/g carbon-free catalyst/hr, and a CO conversion of *circa* 95 per cent was maintained for 216 hr. In Expt 16/14 fresh catalyst was used at a space velocity of 4600/hr (equivalent to only 4·9 litres/g catalyst/hr) and the average CO conversion (which fell rapidly over a period of 72 hr) was 68 per cent. When the fresh catalyst was used in Expt 16/16 at a similar space velocity to that employed with the "diluted" catalyst, the CO conversion was 96 per cent. The apparent catalyst activity in litres $CO + H_2$ converted/100 g catalyst/hr was approximately eight times higher in the diluted state than in the concentrated state. When these results were first obtained [9] it was assumed that they were due to an increase in the intrinsic activity of the iron in the carbon-diluted catalyst brought about by the creation of more active surfaces during the disintegration which accompanies carbon formation, and some support for this view was provided by the results of surface area and CO chemisorption measurements. The results obtained in the slurry reactor, however, suggest that a part or the whole of the explanation might be that the maximum activity of the catalyst is developed only when it is relatively sparsely distributed throughout the reaction zone. Evidence in support of this view is provided by a result quoted in a recent patent.[12] J. E. Latta of the Stanolind Oil and Gas Co. claims that when finely divided mill-scale catalyst is deposited on the walls of a reaction vessel to form a uniform layer 0·01 to 0·06 inch thick and synthesis gas is passed through the otherwise empty vessel under the normal fluid-bed operating conditions the activity of the film of catalyst (cu ft CO converted per lb catalyst per hour) is ten times greater than that of the same catalyst when used in a normal fluidized bed. A similar result has

recently been obtained by the present authors in a fixed-bed reactor. It was found that when catalyst particles of size range 72–170 BSS were supported on a fine-mesh stainless-steel gauze plug which occupied three times the volume which the catalyst alone would occupy in a compact bed, the catalyst activity was doubled. It seems possible, therefore, that the activity of a catalyst as defined in the present paper increases with decrease in the concentration of catalyst in the reaction zone up to a maximum figure, if the time of contact of the reacting gases in the zone is maintained constant. If the concentration is reduced below the minimum necessary for maximum activity, then the time of contact must be increased.

This " dilution " effect tends to interfere with comparison of the performance of the catalyst in the fluid bed with the performance in the other techniques, because in most of the experiments reported in this paper the fluidized catalyst was continually expanding due to carbon formation. When the gas rate was increased in attempts to determine the maximum throughput at which the desired level of conversion (95 per cent) could be maintained, the increase in catalyst volume due to carbon formation tended to keep the space velocity constant or to cause it to fall and, in many cases the conversion rose instead of falling. However, in the short period of operation recorded in Table I as Expt 19/17 there was evidence that the gas rate employed was the maximum for 95 per cent CO conversion, and it is clear that the high throughput used in Expt 16/14 was greatly in excess of this maximum. The results of these experiments can, therefore, be used to gauge the maximum activity of the undiluted catalyst in the fluid-bed system under the particular conditions of temperature and pressure employed.

In the fluid-bed experiment 18/34 (Table III) in which the operating pressure was 600 p.s.i.g., there was practically no bed expansion due to carbon formation, and from the high CO conversion it is evident that the gas rate used was considerably below the limiting value for 95 per cent conversion. In view of the observed effect of pressure on the reaction rate, one can confidently assume that the limiting gas rate (and hence the activity and space–time yield) would have values approximately twice those found in Expt 19/17 for operation at 300 p.s.i.g.

The results summarized in Table IV indicate that when the normal size of granule is used in the fixed bed, the catalyst activity increases in the order fixed bed, liquid phase, fluid bed. When the same size of catalyst particle is used in fixed- and fluid-bed synthesis, however, the reaction rate appears to be higher in the fixed than in the fluid-bed and in both systems three to four times higher than in the liquid-phase. It can be concluded, therefore, that fluidization *per se* does not increase the rate of the synthesis reaction and that the presence of the liquid medium seriously retards the rate in the slurry process.

Clearly, for a given catalyst activity, the space–time yield will increase with increase in the catalyst concentration and, hence, the maximum space–time yield should be obtained in the fixed-bed process, and the lowest in the slurry process. Taking into account the effect of particle size, this is supported by the data in Table IV.

In practice, very small catalyst granules cannot be employed in a fixed bed, and hence, with fused or sintered iron catalysts, maximum space–time

TABLE IV

Summary of Results

Reaction system	Fixed bed			Liquid phase	Fixed bed	Liquid phase	Fluid bed	Fixed bed			Liquid phase	Fluid bed	
Experiment number	12/54	12/54	12/68	17/10	12/54	17/10A	19/17	12/57	12/63	12/68	17/13	18/34	19/17 *
Catalyst	A.S.	A.S. (25–36)	A.S. (72–170)	A.S.	A.S.	A.S.	A.S.	A.S.	A.S. (25–36)	A.S. (72–170)	A.S.	A.S.	A.S.
Operating pressure, p.s.i.g.	300	300	300	300	300	300	300	600	600	600	600	600	600
Operating temperature, °C	265	265	265	265	300	300	305	305	305	305	305	305	305
Space velocity, litres synthesis gas/litre reaction space/hr	427	1235	1775	110	1087	196	2200	2110	7100	9700	516	1400	4400
CO conversion, per cent	94·3	93·5	95·6	94·2	95·3	94·1	95·3	94·0	95·3	98·7	96·2	99·5	95
$CO + H_2$ conversion, per cent	89·2	88·0	95·2	84·1	89·2	84·2	93·0	88·0	90·1	96·2	93·5	96·7	93
Activity, litres $CO + H_2$ converted/100 g catalyst/hr	17·2	50·4	76·8	19·0	44·7	70·6	192·0	86·2	288·0	421	110·0	210·0	384
Space–time yield, litres $CO + H_2$ converted/100 ml reaction space/hr	35·5	104·7	162·7	9·0	92·6	15·5	192·0	178·4	595·0	903	44·6	128·2	384
Selectivity	15·7	18·1	16·2	8·8	17·4	10·9	16·1	13·4	13·9	16·5	11·3	14·7	16
Methane formation, per cent of CO converted													

* Calculated from results obtained at 300 p.s.i.g.

yields are obtained by operation in a fluidized bed. The results indicate that at a given temperature and pressure, this maximum yield would be of the order of ten times that obtainable in the slurry system.

It will be noted that hydrogen utilization tends to be greater in the fluid bed than in the other techniques, and in certain cases greater in the liquid phase than in the fixed bed. This is due to differences in recycle ratio and level of conversion rather than to a specific property of the reaction system used. An increase in CO conversion and/or in the recycle ratio leads to increased hydrogen utilization. Further reference to these effects will be made below.

Selectivity and Product Composition

Some idea of the selectivity obtained in the various techniques can be derived from the relative yields of methane and higher hydrocarbons, but a more reliable indication is given by the methane formation expressed as a percentage of the total CO converted. These figures are given in Table IV, whence it will be seen that methane formation is lowest in the liquid phase and approximately the same in the fixed and fluidized beds. The results obtained at 600 p.s.i.g. show a smaller difference in selectivity than those obtained at 300 p.s.i.g. This is because in the fixed and fluidized beds methane formation was reduced by doubling the pressure, whereas in the liquid phase the methane formation was slightly higher at the higher pressure. This result is considered to be misleading, because in the study of the effect of pressure in the slurry system (see Table II), methane formation fell consistently with successive increases in operating pressure at constant temperature and time of contact. The fact that the methane formation showed no fall in Expt 17/13 at 600 p.s.i.g. compared with Expt 17/10A at 300 p.s.i.g. may be due to the fact that the temperature and level of conversion were somewhat higher in the former than in the latter.

The boiling range of the liquid products appeared to vary with gas throughput and conversion level, but from a study of the data in Tables I and III it is evident that the boiling range is essentially independent of the process technique employed. Thus, with ammonia-synthesis catalyst operated at 305° C and a CO conversion of *circa* 96 per cent, the fraction distilling below 200° C is between 70 and 80 per cent, the diesel-oil fraction between 12 and 18 per cent, and the heavy oil and wax 7 to 12 per cent of the C_{5+} product, irrespective of the process technique employed.

The olefin contents of the spirit fraction are, in general, lowest in the fixed bed and highest in the fluid bed, but there is considerable variation in the olefin content of products obtained by the same technique at the same reaction temperature, and there is a tendency for the olefin content to fall with increase in the partial pressure of hydrogen in the total reactor feed.

In experiments with ammonia-synthesis catalyst, the proportion of oxygen-containing products was greatest in the liquid phase and least in the fluid-bed system. With the mill-scale catalyst in fixed and fluid-bed experiments, if the greater yield of water-soluble alcohols and acids obtained in the latter process is offset against the lower proportion of oil-soluble compounds there would appear to be little difference in the total amount of oxygenated products produced in these two cases.

Carbon Formation

In the results of tests at 300 p.s.i.g. recorded in Table I, there is a striking contrast between the very low carbon formation in the liquid phase and the very high carbon formation in the fluid bed at the same temperature. In Table III the results of tests at 600 p.s.i.g. show low carbon formation in fixed-bed and liquid-phase operation and for one of the fluid-bed tests a high carbon formation (of the same order as those in Table I) and for the other, a carbon figure of the same low order as those obtained in the fixed-bed and liquid-phase tests. It will be observed that the higher carbon figure was obtained in an experiment where the hydrogen partial pressure in the total reactor feed was 100 p.s.i.g. and the low figure, when the partial pressure was 199 p.s.i.g. In a recent paper [7] Arnold and Keith

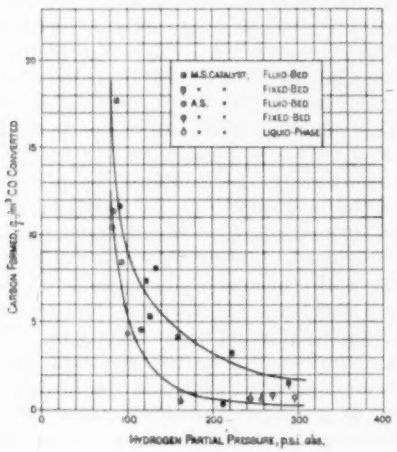

FIG 7

RELATION BETWEEN CARBON FORMATION AND HYDROGEN PARTIAL PRESSURE AT REACTOR INLET

showed, as a result of a very large number of experiments, that the hydrogen partial pressure in the reactor feed was the main factor controlling carbon formation in the fluidized-catalyst ("Hydrocol") process. They plot a curve which shows that the extent of carbon formation rises very steeply when the hydrogen partial pressure falls below 100 to 125 p.s.i.a. In Fig 7 the carbon formation obtained in the present experiments (together with data from a number of other experiments in the fluid-bed reactors) is plotted against hydrogen partial pressure, and it will be seen that the data from experiments with all three process techniques can be represented by two curves, one for each type of catalyst. The curve for the ammonia-synthesis catalyst is very similar in shape to that published by Arnold and Keith, but with the change in direction occurring in the region of 150 p.s.i.a. hydrogen pressure. The fact that the curve for the mill-scale catalyst lies above the other curve and falls less steeply with rise in hydrogen

pressure is consistent with the known greater activity for carbon formation of this catalyst compared with the ammonia-synthesis catalyst.

The hydrogen partial pressure is controlled by the total (operating) pressure and the $H_2 : CO$ usage ratio, which in turn is controlled by the recycle ratio and by the extent of conversion of the synthesis gas to hydrocarbons. With a high recycle ratio and/or a high level of conversion the formation of hydrogen and CO_2 by the water-gas shift reaction is suppressed; at lower conversions or with low recycle ratios the shift reaction proceeds to a greater extent, more hydrogen is present in the reactor exit gas, and hence more in the total inlet gas.

Arnold and Keith state [7] that the shift reaction is always close to equilibrium under the conditions used in the fluid-catalyst process. Kassel [13] gives the equilibrium constant ($pCO \times pH_2O/pH_2 \times pCO_2$) as 0·0371 at 327° C. From the composition of the reactor exit gases for Expts 18/31 and 18/34, values of 0·035 and 0·039, respectively, were obtained, indicating that in these cases equilibrium had, in fact, been reached. For the fixed-bed experiment 12/57, however, the value obtained was 0·125, suggesting that equilibrium had not been reached in this case, possibly due to the lower activity of the large catalyst granules used.

Attention has already been drawn to the apparent tendency for hydrogen utilization to increase in the order fixed bed, liquid phase, fluid bed, and it will be noted that the hydrogen partial pressure in the reactor feed decreases, as might be anticipated, in the same order. As indicated previously, where this trend appears, it will be found that either the recycle ratio or the conversion increases in this order, *i.e.*, the effect is due to variation in the operating conditions, and not to change in the process technique.

Composition of the Used Catalysts

In Table III the composition of the catalysts after use in experiments at 600 p.s.i.g. is recorded. It will be noted that in the fixed-bed experiment 12/57, in which the temperature did not exceed 305° C, the catalyst contained practically no free carbon. The catalyst used for Expt 18/34 in the fluid-bed reactor contained 14·9 per cent total carbon. Hence, only a relatively small proportion of the carbon found in the used catalyst was produced during the experiment. Similar considerations apply to Expt 17/13 in the liquid-phase reactor, where the original catalyst contained 4·4 per cent total carbon.

The most striking feature of the results is the variation in the oxide content of the catalysts. From equilibrium data for the oxidation of iron by steam and by CO_2 and the composition of the exit gases it can be deduced that the conditions at the outlet of the reactor were in all cases strongly oxidizing. The following data illustrate this :—

Expt No.	18/31	18/34	12/57	K_{eq}[1]
pH_2O/pH_2	0·167	0·667	0·258	0·044 at 300° C
pCO_2/pCO	4·75	21	2·08	1·56 at 327° C

The fact that the conditions in 18/34 were more conducive to oxidation than those in 18/31 is in conformity with the oxide contents of the catalysts from these two experiments, but from the above figures one would not expect the catalyst from the fixed-bed experiment 12/57 to have a

higher oxide content than that from Expt 18/34. It may be that in the fluidized system the continual circulation of catalyst from the top of the bed (where conditions favour oxidation) to the bottom (where conditions favour reduction) results in a final state of oxidation which is less characteristic of the exit gas composition than is the case in the static system.

If the oxide contents shown in Table III are expressed on a basis of carbon-free catalyst they are found to vary directly with the partial pressure of hydrogen in the total reactor feed. This relationship, for which it is difficult to find any simple explanation, may be purely fortuitous.

Technical Implications of the Results

It is clear from the foregoing that a particular catalyst when operated under similar conditions of gas composition, temperature, pressure, recycle ratio, etc., gives essentially similar results in a fixed-bed, liquid-phase or fluidized-bed system, on a laboratory scale. With fused and sintered catalysts, however, the maximum activity of the catalyst can only be realized in the fluid-bed process, because advantage can be taken of the higher activity of small catalyst particles and because there is no liquid medium present to exert a retarding effect on the reaction rate. For the same reasons, and because the concentration of catalyst per unit of reactor volume is low in the slurry process, the maximum space–time yield is also obtained in the fluid-bed process. Maximum selectivity, however, is obtained in the slurry process; this is attributed to the virtual impossibility of obtaining overheating of the catalyst particles in this system.

These conclusions are based on experiments in which the three process techniques were restricted to a common set of conditions, whereas, in technical practice, the slurry and fixed-bed processes could be operated under quite different conditions. Thus, in the slurry process, where mechanically robust catalysts are not essential, precipitated catalysts of higher activity than the fused and sintered catalysts used in the present work could be employed, with a feed gas of much lower $H_2 : CO$ ratio. Such a gas would be cheaper to produce than H_2-rich gas, and its use would increase selectivity and reduce or eliminate the cost of gas recirculation. It is considered, however, that the rate of reaction in the fluidized bed is so much greater than in the slurry system, the advantage in space–time yield would still lie with the former process.

The fixed-bed results obtained in this work suggest that by operating with the normal size of catalyst granule at 600 p.s.i.g. and 300° C with gas recirculation, complete conversion of the gas in one stage could be achieved at space-velocities of 2000 vol fresh gas/vol reaction space/hr without formation of free carbon, provided that the heat of reaction could be dissipated as effectively in a full-scale reactor as in the laboratory reactor. This appears to be extremely unlikely, but it is of interest to note that the Ruhrchemie A.G. have recently achieved successful fixed-bed operation with iron catalysts, over prolonged periods, in water-cooled tubes of the same dimensions as would be used on the commercial scale, at hourly fresh-gas space velocities of 500. To achieve this result gas recycle is employed and the dimensions of the tube chosen to give a high linear velocity.[14]

Apart from the heat-transfer problem, the fixed-bed system must always

suffer from the limitation on operating conditions imposed by the absolute necessity for avoiding carbon formation, and must lack the advantage possessed by the liquid-phase and fluid-bed processes of ease of catalyst replacement.

In the introductory section of this paper the fluid-bed system was described as being limited to conditions which gave products of low molecular weight and which minimized carbon formation and, as a consequence of this, the selectivity of the process was poor. It is clear from the results reported here that the only limitation which is a direct consequence of the use of the fluidization principle is that which concerns the molecular weight of the products, and when motor fuel is the major requirement of the process, this can hardly be rated as a disadvantage. Thus, if a catalyst is chosen which gives a predominantly low-boiling product at temperatures below the range in which carbon formation is excessive, then a feed gas of low $H_2 : CO$ ratio can be employed and improved selectivity be achieved. The nitrided iron catalyst developed by the U.S. Bureau of Mines [15] is of high activity, and produces an almost wax-free product at low reaction temperatures. A nitrided mill-scale catalyst was successfully employed by the present authors in a fluid-bed reactor at 250° C with no agglomeration of the catalyst particles and no free carbon formation. The selectivity was poor, however, and the products contained an undesirably low proportion of olefins and a high proportion of oxygen-containing compounds. By further catalyst development it should be possible to remove some of the limitations of the fluid-bed system while retaining its present advantages.

In view of the indications that the activity of the catalyst increases with the degree of dispersion throughout the reaction zone, maximum utilization of the catalyst (although not, necessarily, maximum space–time yield) should be obtained in a "dilute-phase" operation, in which the catalyst is completely dispersed in the gas instead of being confined in a dense-phase fluid bed.

Although the choice of process technique for commercial use will depend on the economic effects of such factors as selectivity, space–time yield, gas composition, operating pressure, and recycle ratio, the over-riding consideration is whether the process has been proved to be operable, *i.e.*, whether it can be operated for periods of many months with constant gas conversion and constant yields of products of uniform quality. The work described in this paper provides no information on this question, as operability can be assessed only by pilot-plant work on a scale such that translation to the full scale can be made with reasonable certainty of avoiding scaling-up effects. On the information available at the time of writing, it would appear that the only technique of proved operability is the Ruhrchemie fixed-bed process.

Conclusions

Synthesis experiments have been carried out with fused and sintered iron catalysts in laboratory-scale, fixed-bed, liquid-phase (slurry), and fluidized-bed reactors under similar reaction conditions, and the following conclusions have been drawn :—

1. Allowing for the increase in activity which accompanies reduction in the particle size of fused and sintered iron catalysts, the reaction rate in a fixed bed is the same as or somewhat greater than that in a fluidized bed, but in a slurry system the rate is appreciably lower. The space–time yield, which is dependent on catalyst concentration, is potentially greatest in the fixed bed and lowest in the liquid-phase. In practice the highest space–time yield would be obtained in a fluidized bed. Fluidization, *per se*, does not increase the rate of reaction, but the presence of the liquid medium in the slurry process retards the reaction rate.

2. Selectivity is approximately the same in the fixed and fluid beds, but is appreciably higher in the slurry system. This is attributed to the direct contact between catalyst particles and liquid medium in the slurry process, preventing any possibility of local high temperatures.

3. The boiling range and olefin contents of the liquid products are independent of the synthesis technique employed.

4. With a particular catalyst and reaction temperature carbon formation is controlled by the partial pressure of hydrogen in the total reactor feed (in confirmation of the results of Arnold and Keith [7]), and is independent of the nature of the process technique.

5. The rate of the synthesis reaction is a linear function of operating pressure over the range 300 to 675 p.s.i.g. in all three processes.

6. The synthesis-gas space velocity (time of contact of the gas in the reaction zone) exerts a greater control over the reaction rate than the gas throughput per unit weight of catalyst.

7. The activity of the catalyst increases with decrease in its concentration in the reaction zone.

8. There appear to be possibilities of increasing the space–time yield obtainable in practice by the fixed-bed technique and of increasing the selectivity of the fluid-bed process, but it is considered that maximum selectivity and flexibility will always be obtained in a liquid-phase system.

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Key to Figs 1, 2, *and* 4

A. Compressed synthesis gas
B. Pressure regulator
C. Rotameters
D. Preheater
E. Reaction vessel
F. Heated receiver
G. Water-cooled condenser
H. Gas/liquid separator
I. Atmospheric-pressure receiver
J. Pressure let-down controller
K. Traps cooled in dry ice
L. Residual gas meter
M. Diaphragm-type recycle pump
N. Pressure-difference gauge
P. Pressure gauges
Q. Partial condenser
R. Sintered-bronze filter
S. Steel ball
T. Thermocouples

Discussion

Dr M. A. Matthews: In a paper published at the beginning of this year Eugene Ayres gives future forecasts of oil reserves, demand, and production on the basis of present growth trends. By assuming an additional petroleum production of 1 trillion (10^{12}) brl of oil in the world, *i.e.*, more than ten times present proved reserves of the world, it is estimated that with present growth trends there will be a world shortage of petroleum by 1970—a shortage that will rapidly become more substantial as demand rises in later years. When the U.S. alone is considered, and assuming the future producible amount of petroleum is 100 billion brl (more than three times present proved reserves)—a shortage of domestically produced petroleum is already beginning to be felt and will increase moderately until 1960 and sharply between 1960 and 1970, by which time the world shortage will begin to be felt. Based on such calculations, Ayres concludes that alternative supplies will first come from oil shale, but because this won't be able to supply the whole of the gap it will be essential to have utilization of coal—probably by Fischer–Tropsch—well under way by 1970 and operating on a very large scale by 1980.

Dr Hall has referred to the plant at Brownsville for the conversion of natural gas into oil. That was conceived about 1945 and, although it is understood to be operating, there has, as far as I am aware, been yet no official announcement of the successful achievement of design output. That is a period of seven years, and on the calculations I have referred to, there are only eighteen years left to get into full operation the really large-scale industrial process of the much more complicated conversion of coal into oil. I mention all this because the sort of work that is described by the authors of the present paper is very essential groundwork for such envisaged industrialization.

I find the references to the time of contact in the slurry process a little confusing. Surely the time of contact of a gas in a liquid-phase reaction has a different meaning from the time of contact in, say, a fixed bed, and it is in fact one of the relative inflexibilities of the liquid phase process. The time of contact will depend on the rate of bubble rise, which in itself will be dependent on a number of physical properties of the gas and of the liquid but which for all practical purposes is likely to be constant for any conditions of operation within the range considered in the paper. Take the case of one bubble of gas in unit time. Then if the bubble rises at the rate of, say 1 ft/sec, and I presume this will be approximately the rate for these experiments, then in the slurry converter used in these experiments of about 3 ft in height, the time that the gas has a chance of contacting the catalyst will be 3 sec. If the gas rate is doubled to give two bubbles in unit time, both bubbles will ascend at the same rate, and the time will still be 3 sec; and this will persist in a given reaction volume until foaming conditions are reached, *i.e.*, when the contents of the reactor consist of oil and catalyst in gas as compared with gas in oil—similar to the changeover from fluid bed to suspensoid operation. Thus, in this slurry reaction the only real way of altering the real gas time of contact is by changing the height of the converter. Large scale plant would almost certainly operate with tall converters, and therefore in any comparison of methods of operating Fischer–Tropsch due account should be taken of the height of converter. I should therefore like to ask the authors whether the effect of height of converter or reaction catalyst bed has been examined. In this connexion I note that the fluid reactor was 244 cm long and the slurry 92 cm.

I think it would be of some interest to know what is the mechanism of the slurry stage. Surely it must mean that the H_2 and CO dissolve in the liquid medium and then react from the liquid on the catalyst surface. It will depend on what part of the cycle is the limiting factor, but I would like to ask whether the relative solubilities of H_2 and CO in the oil used have been determined under the conditions of the reaction—I seem to remember that the solubility of H_2 in oil increases with increasing temperature, and it would therefore be of importance to know the solubilities under the reaction conditions. It might be expected that in order to maintain the same ratio of H_2 to CO in the liquid as is met with in the gas phase in the fixed or fluid bed reactors, it might be necessary to operate with quite different H_2 and CO partial pressures in the gas phase of the slurry reactor.

Reference is made in the paper to the improved selectivity in the liquid phase being due to the more even temperature distribution and the virtual impossibility of having any hot spots or very local increases in temperature. From a general knowledge of large scale liquid phase and fluid-bed reactions, I should doubt whether the temperature distribution in a large scale, liquid phase reactor was any better than a large scale fluid bed. If, therefore, this temperature effect is the cause of the difference in results in the present experiments, I would expect such a difference to disappear in a commercial scale plant. In this connexion, therefore, I would like to ask whether any practical evidence was obtained in the course of these small scale experiments that temperature distribution, or rather local overheating, was any better in the liquid phase than in the fluid-bed system?

One other question on the liquid phase. Have any experiments been

made on the effect of using different oil media in the slurry system? I know that application to the large scale would present difficulties in separating the heavy waxy oil made in the process from a different liquid medium, although such a separation would not necessarily impose insuperable difficulties, but I ask the question more from the theoretical aspect, particularly in relation to different gas solubilities in the oil and different conditions at the catalyst/oil interface.

In the section of the paper dealing with the technical implications of the process, reference is made to the rate of reaction being so much greater in the fluidized bed as compared with the slurry system, and that that fact rather tends to outweigh the better yields from the slurry process. I think that in the technical application it is necessary to be a little careful about that comparison, because if a commercial system is laid out, going from coal to oil, the actual capital cost of the reactor system itself is somewhere between 5 and 10 per cent of the total. Therefore, if there is a system giving rather better yields but needing 50 or 100 per cent more reaction volume, the increase in total capital cost would not be so large. On the other hand, if the volume required for the slurry system is something like ten times that for the fluid bed, it will have a big effect on the total capital cost.

Dr Hall: We have explored the height effect in the reactor, but only over the range of about 8 to 30 inches, and over that range we have observed no effect. Kölbel, who worked in the pressure range of 5 to 10 atm (whereas ours is 30 to 40 atm), said there was at those low pressures a marked height effect; he said there was a positive height effect from the sort of heights we used up to about 12 ft, and after that he did not observe any great effects. He attributes the difference between our results and his to the different size of bubbles and to the difference in height. But we are doing some work which will give more data on height effect.

As to the mechanism, we have not actually determined the relative solubilities of CO and hydrogen under the conditions of operation used, but from the data in the literature we found that there was not much difference between them under the conditions we were using. If, as you say, there was a tendency for hydrogen to be the more soluble there should be a tendency to get high methane formation, which we did not observe.

On the question of the temperature control in the various systems, so far as our observations are concerned, we did get indications of temperature differences in our tall, narrow, baffled fluid beds which we did not observe at all in the slurry process, where the temperature was remarkably uniform. We heated only one-half or two-thirds of the length of the reactor, and the portion of the slurry which was outside the heating zone maintained the same temperature as that portion which was within the zone of the electric heater. We also feel that fluidization as carried out technically is very crude, in that there are very large bubbles of gas going through the reactor, and that there are greater chances of local overheating in such a system than in one where every particle of catalyst is separated from the next by a film of oil.

The effect of the slurry medium has not been studied, and it is difficult to do so because, whether we start from hard wax or diesel oil, before running

for very long the slurry medium will be wax. Unless the wax is continually removed there is no control of the composition of the slurry medium.

As to the relative economic effects of specific yield per cubic metre and space–time yield, I tried to be very careful not to specify that one was more important than the other. I think we stated in the paper that, although the space–time yield of the slurry process could be improved by using a more active catalyst, the advantage in space–time yield would probably remain with the fluidized-bed process. The economic effects of space–time yield, selectivity, and yield per cubic metre will all have to be taken into account.

DR GALL : There is a point in which Dr Matthews may be interested; it is something which is not drawn from our own experience. Kölbel claims that he obtains conversion of his medium during synthesis. If he starts with diesel oil, he can convert it into wax. Similarly, if he starts with wax he obtains increased yields of light hydrocarbons.

DR MATTHEWS : On the question of the oil media, I was thinking of taking one of an entirely different composition, such as an aromatic oil. One would, of course, have to remove this oil with the wax, but I wondered what effect the presence of a different oil might have on the process as a whole.

DR HALL : That is certainly worth exploring.

DR L. S. THORNES : I must congratulate the authors on the effort and patience that must have been expended in obtaining the information which has been presented in this paper. Having been directly connected with catalyst testing for some years, I can appreciate the practical difficulties that must have been involved in obtaining the information with equipment of such a small size. The pressure operation of a 14-mm bore fluidized-bed reactor is of particular interest, as it is a development that has frequently been impressed upon me as a bench scale alternative to the much more expensive pilot plant testing which has been used in catalytic cracking and reforming processes. I think it is fair to say that a large amount of published data obtained from fixed-bed catalyst testing for all processes can be very misleading, as the precision and repeatability of such tests is very poor. I particularly have in mind one activity test which is frequently made on cracking catalysts at atmospheric pressure in which it is possible, with reasonable care, to obtain duplicate or triplicate determinations on a single charge of catalyst with an accuracy of the order of ± 2 per cent.

Repeat tests, made after the reactor has been emptied and re-charged with either the same or a similar batch of fresh catalyst, while still giving results which have the same degree of consistency, may often show a deviation of as much as 8 per cent from the original data. The use of 7 to 14 BSS catalyst (1·2 to 2·4 mm) in the 10-mm bore tube is obviously liable to give difficulties in this respect. My experience of testing similar catalysts in powdered form using fixed fluidized technique has shown much worse repeatability. German workers themselves admit that catalyst differences

which do not show up on the bench scale can have large benefits on commercial size units (*i.e.*, MgO promoted catalysts.)

From the point of view of a petroleum technologist, the paper is incomplete in that it does not give information by which the process can be assessed as a producer for automotive fuels. This is, perhaps, understandable with the small scale of operations employed, but it must be realized that, as the liquid products from these processes may only be the feedstocks for further conversion and up-grading processes, it is essential that large quantities of products be made available for evaluation before any decision can be reached on the value of the processes as a whole.

As I understand the paper, the work was directly concerned with a comparison of the three operational techniques for the production of liquid automotive fuels as an alternative to natural petroleum and, as such, the experiments were made to provide a direct comparison when using substantially the same processing conditions. In each case, pressure, temperature, and gas composition were kept constant, but it is not at all certain that the process conditions were, in fact, the optimum for any of the three processes examined.

For example, for fixed-bed work a value of 250° to 275° C is normal; for the " Slurry " process the temperature range is usually 245° to 255° C, while for the most recent fluidized processing (Keith) temperatures in the range 330° to 350° C are employed.

One other feature which makes it difficult to discriminate between the three processes is the fact that in all cases process conditions have been set to obtain carbon monoxide conversions of 95 per cent and, consequently, the relative benefits of any method of operation is unlikely to be clearly indicated. It would, therefore, be very unwise to take the data as presented in this paper and attempt to use it scaled up directly for full scale design purposes. The simplification of reactor design and operation made possible by the fluid or slurry processes will obviously weigh strongly in favour of these methods, and some reduction in efficiency could perhaps be tolerated.

The authors themselves are obviously aware of these difficulties and, in concluding that the intrinsic catalyst activity is the same for fixed- or fluidized-bed conditions, and that the nature of the liquid products is substantially independent of the process used, they are in effect saying that the further development of the Fischer–Tropsch synthesis will be governed by the economics of processing costs rather than on large differences in yield and qualities of the liquid products resulting from either process. This information can only be obtained as a result of much further work on the pilot plant and semi-commercial scale operations.

In developing a new process or technique such as that described in this paper, it should be realized that before it can be considered for application to the commercial scale it must be proven on a pilot plant of sufficient dimensions so as to provide not only process data but also the chemical engineering information necessary to enable the full scale unit to be designed with confidence. The precise scale of operations for a process of this type would need a careful consideration of the various steps about which scaling information was lacking—it is my opinion that the probable minimum scale would be approximately thirty tons/day.

DR GALL: On the question of the consistency or reproducibility of results we have a number of fixed-bed converters ranging from about 8 mm to more than 12 mm diameter and have found that the results are fairly reproducible; two different converters charged with the same catalyst, or with different batches of catalyst of the same composition give the same results. It is realized that there are some limitations in respect of the size of the converters, but it is felt that the results produced from them are reasonably reliable.

The problem of the fluidized-bed reactor is rather different, as it is not quite so easy to operate under standard conditions. Reasonably good duplication of results in the ½- and 1-inch diameter reactors have been obtained.

DR HALL: On the question of the application of the results to the large scale, it is pointed out in the paper that this was not possible and that pilot-plant operations on an adequate scale were necessary to establish the relative merits of the individual process techniques for commercial purposes. It is also pointed out that to permit the desired comparisons of reaction rate, selectivity, product composition, etc., to be made, the three techniques had to be used under a common set of conditions which were not necessarily the optimum ones for any of the techniques examined.

MR DUNSTAN: Reference has been made to catalyst particle size, but no reference was made to gas bubble size which I presume occurs in the fluid catalyst. I should have thought that would have had a pronounced effect on the subsequent reaction.

DR HALL: I think it certainly has. When we did our tests with extremely small particles (say 100 mesh average) in the fixed bed, our bubble size was extremely small; it had to be, because all the gas passed through the interstices between the very small particles, whereas in the fluidized-bed system the bubbles could be of up to ½ inch diameter. Bubble size was not measured, but it may play a part in explaining why the fixed bed appeared to be more active than the fluidized bed.

MR DUNSTAN: In certain reactions of that type, sintered glass is used for gas distribution; it gives very fine bubble size and an enormous number of bubbles.

DR HALL: That was tried in early slurry experiments in Germany. Nearly everybody who experimented with the slurry process—and three or four German organizations did so—started with filter plates; but they obtained results just as good by bringing in the gas through a ½-inch pipe, the answer being, I think, that the bubbles reached a constant size at a relatively short distance above the point of entry of the gas, so that they did not improve matters by having a fine gas distribution at the point of inlet. They obtained a rate of reaction every bit as high when the gas was passed in through the ½-inch pipe as when they used sintered or ceramic materials.

W. W. ELLIOTT : My main interest in this matter has been from the point of view of the catalyst bed rather than that of the Fischer–Tropsch reaction. I have been trying to think whether mass transfer or rate of chemical reaction governs the conversion. It seems to me that mass transfer is very important here. It may well account for what Dr Matthews has mentioned concerning solubility and the slurry type process and for the low intrinsic activity of the catalyst in the slurry. Also it appears to me that if chemical reaction was the controlling factor, in a fluidized bed of relatively high surface area there could be a larger increase in throughput than is actually observed. Another point of interest in this connexion is the novel effect of the dispersion of the catalyst on the walls of the reactor tube.

I should like to hear the views of the authors on these points and on whether they are attempting to make comparisons, from a chemist's point of view, of processes which are engineering problems, and processes that are controlled by rate of mass transfer.

DR HALL : I think that mass transfer is important in the slurry process. It is not thought solubility is important, and it is believed that it is the rate of diffusion of reactants to, and products from, the catalyst surface that controls the rate of reaction. It would be interesting to know if others have experienced the effect of " spreading out " or dilution on catalyst activity. Apparently, with a close-packed bed use cannot be made of all the catalyst surface, but fuller use can be made of it when the particles are distributed throughout the reaction zone. I think the experiments showed that the controlling effect was the time of contact of gas in a zone containing the catalyst and not the litres passed per gram of catalyst, although, obviously, there must be a limit to the amount of gas which a gram of catalyst will convert at a certain level of conversion.

DR THORNES : About the increase of catalyst activity, it could be that the carbon deposited in the catalyst during the reaction has an effect.

DR HALL : It is not believed that the carbon deposited in the catalyst has any specific catalytic activity. It is considered that the expansion of the catalyst as a result of carbon formation leads to an increase in the activity of the catalyst per unit weight by the dilution effect observed in the slurry experiments and experiments with a wire-gauze support. There is some evidence from CO chemi-sorption experiments that there is, in addition, an increase in the intrinsic activity of the iron due to an increase in its surface area caused by the opening-up of the catalyst structure when carbon is formed within the particles.

R. TURNER : Has this increase of activity with decrease of particle size been correlated with the corresponding increase of surface area ?

DR HALL : The surface area of the unreduced catalyst is pretty well the geometric surface area. The surface area of the reduced catalyst, when determined by the Brunauer, Emmett, and Teller method, shows very little variation with particle size. The activity increases with the geometric

surface area, suggesting that only a thin skin of each particle is active for the synthesis. I think that is the explanation of the particle size effect.

H. C. RAMPTON : I should like Dr Hall and his colleagues to answer one or two analytical questions. I am interested in hydrocarbons as such, and in any process of this nature the ultimate value lies in the usefulness of the hydrocarbon products. In this connexion, was any attempt made to analyse these and to determine contents of individual compounds? The concentration of normal paraffins is, of course, expected to be high, but, as a result of any differences in the various techniques employed, was there any sign of isomerization or, even, cyclization?

DR GALL : I regret to say that we have not examined the products from the three processes in detail, and have no information regarding the distribution of individual hydrocarbons or the presence of isomers, cyclic compounds, etc. As stated in the paper the reaction products were examined only to the extent necessary to reveal major changes in composition.

W. LOWENSTEIN-LOM : Can Dr Hall comment on two German claims, one by Kölbel and Ackermann to the effect that the yield of oxygenated compounds, and particularly alcohol, could be considerably increased by the oxyl process?

The other claim is made by Kölbel. I believe that the synthesis gas composition can vary over a much wider range under the conditions of experiment which he has been using.

DR HALL : I am not familiar with the details of the oxyl process, except that it is an iron catalyst process operating, I believe, at 30 atm ; otherwise it is a conventional Fischer–Tropsch operation. All I can say is that there is nothing extraordinary about the claims made. In our experiments a very wide range of contents of oxygenated compounds were observed with changing conditions, so that I have no reason to doubt the claims made for the oxyl process. I think it is probably the result of applying all those factors which are known to increase the yield of oxygenated compounds, factors such as short time of contact, low temperatures, high pressures, and so on, possibly with modification of the catalyst.

Kölbel's steam/CO reaction is a logical development of his own and American work ; CO and water can certainly be used as feed materials. That has been checked by operating a fluidized reactor on water-gas and steam, and it has worked quite nicely. I think it would be perfectly possible to operate with producer gas or blast furnace gas and water. Probably it would be rather cheaper than using more conventional gas mixtures.

D. J. HADLEY : What weight of catalyst is carried off the fluidized bed, and is that of economic importance?

DR HALL : It is a little difficult to put it in terms of weight. An experiment is quoted in the paper where in the course of forty days, starting with half a litre of fresh catalyst, 10 litres of fine dust was carried over.

That was under severe carbon-making conditions, not using a high partial pressure of hydrogen which restricts carbonation. When the carbonation is reduced in this way the carry-over is quite small. I do not think that catalyst loss overhead would be a serious hindrance to the operation of the fluidized-bed Fischer–Tropsch process. There are very much more serious hindrances; wax formation is one of them.

MR ELLIOTT: Would there have been several patents on taking off the fines?

DR HALL: Yes. A reactor with overflow has been operated to prevent the bed expanding and a constant bed volume has been worked. Expansion of the bed in the fluid-catalyst runs presented one of the difficulties in the experiments described in the paper.

DR THORNES: Does not that mean that in the end you must operate on the regenerative process or with a regular catalyst discard? Do you consider the slurry type would also be operated as a regenerative type, or with high catalyst discard rates?

DR HALL: I think both processes would be operated on the discard/replacement system. Our preferred catalyst is mill-scale impregnated with potassium carbonate and sintered at 1000° C for a couple of hours. With such a cheap catalyst one would not attempt regeneration.

A pilot plant has been built at Greenwich of 8 inches diameter for fluid-bed synthesis to operate by discarding from the top by overflow and making-up from the bottom, introducing the catalyst at the required rate to maintain production. From some data obtained from a smaller reactor on that principle a figure something like 1 lb of catalyst discarded for every 20 gal of product produced was arrived at. That is the only way in which to express catalyst life in a fluidized-bed process. It cannot be said that its life is "*X* months."

R. TURNER: Thinking of your suggestion about the use of the dilute phase, has anybody considered the possibility of using a supported catalyst, *i.e.*, one in a dilute form in a dense bed, supported by a relatively inert carrier? Would you get increased activity in that way?

DR HALL: One attempt was made to do that by supporting the catalyst on clay. A mixture of iron oxide and clay was fired, as in making pottery, and found to be somewhat more active than undiluted catalyst on the basis of grams of iron, but not in terms of reaction space. The importance must not be exaggerated of the increased activity obtained in an expanded dilute condition, because that merely makes the maximum possible use of a gram of iron, whereas I think you are more concerned with making the maximum possible use of the reaction space. I think the best way to make use of the observation that the catalyst tends to be more active when spread out is to use the dilute-phase system—rather than a dense-phase fluid bed.

MR ELLIOTT: Does not the space–time yield vary with concentration of catalyst?

DR HALL: Yes, for a given activity, the space–time yield varies directly with catalyst concentration.

MR ELLIOTT: What is the economic thing to do? I have read that it is possible to dehydrate, and so on, and to send the products back to the synthesis gas producer and, in fact, to do anything but separate them.

DR HALL: I would rather not enter into that, except to say that probably in a highly industrialized country it would be worth separating the oxygenated compounds—say for the first half million tons of oil production per year. After that the chemical market might be swamped. In certain areas there is a water supply problem and no outlet for oxygenated chemicals. In these cases the reaction water could be returned to the gasification plant and the carbon in the organic compounds recovered as carbon monoxide.

DR GALL: It is not too difficult to separate the oxygenated products from the reaction water, but there are problems in the separation of the mixture of oxygenated compounds obtained. If it is wished to market chemicals such as butyl alcohol they will have to meet specifications for purity which might be difficult to meet when starting from Fischer–Tropsch product. That consideration would apply even more to the non-alcoholic oxygenated compounds; their separation in a pure state would be extremely difficult, although they would command a high price if isolated. I think, therefore, that you should recover the ethyl alcohol, which would be fairly simple, but should not try to separate the other oxygenated compounds unless the market was very favourable.

E. J. DUNSTAN: I should like to say to the authors, assuming their comments with regard to the oil industry are correct, that there are, of course, two things to take into consideration. One is the somewhat large number of pre-occupations which the industry has had over the last year or two, and the other is the fact that the DSIR rather tends to hide its light under a bushel. To-day I agree that these gentlemen have done something to offset that.

We are really indebted to the authors for their work. We must admit that interest in the subject, at least among those present at this meeting, is quite intense, and we can only hope that the work the authors are doing, with perhaps a little more broadcasting of knowledge on the subject—especially when we consider what the coal industry has to do to set itself up on its feet—will get us somewhere, although the eighteen years which Dr Matthews gives us is a very short time.

On behalf of the Institute I would thank the authors very much for their contribution to our work. This is the place where subjects of this kind should be ventilated.

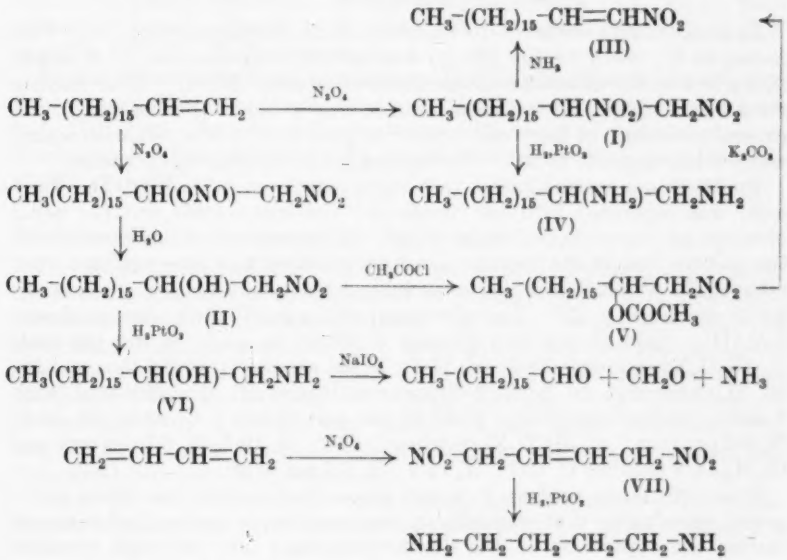
(The vote of thanks to the authors was warmly accorded, and Dr Hall briefly acknowledged it on their behalf.)

THE REACTION OF DINITROGEN TETROXIDE WITH OLEFINS. OCTADEC-1-ENE AND BUTA-1 : 3-DIENE

By C. R. Porter * and B. Wood *

In a continuation of the work previously reported,[1] the liquid-phase reactions of dinitrogen tetroxide with olefins have been further examined as a possible means of characterizing the latter.

This present work extends the investigation to octadec-1-ene and buta-1 : 3-diene; the former of these olefins being chosen in order to ascertain what effect a lengthening of the carbon chain has on the properties and ease of separation of the products formed. Buta-1 : 3-diene was studied as an example of a conjugated diene. The results obtained with both these olefins support the conclusion reached previously,[1] namely, that the oxides of nitrogen are not suitable reagents for the general characterization and analysis of olefins. The principal reactions investigated are outlined schematically below.



The addition of tetroxide to octadec-1-ene occurred in the normal manner,[3] viz., (i) dinitro addition to give 1 : 2-dinitro-octadecane [formula (I)], and

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(ii) nitro-nitrite addition to give after hydrolysis 1-nitro-octadecan-2-ol (II). Both modes of addition occurred to a similar extent in high overall yield (92 per cent), though the dinitroparaffin (I) was only obtained in an impure state.

Tetroxide addition to buta-1 : 3-diene, in both 1 : 1 and 2 : 1 molar proportions, gave the crystalline 1 : 4-dinitrobut-2-ene (VII) in 12·5 and 14·5 per cent yields respectively, hence confirming the previously reported [7] formation of this compound.

The other addition products were, from both reactions, highly unstable liquids which were not identified.

Experimental

Reagents

Pure liquid dinitrogen tetroxide was prepared as previously described.[1] Octadec-1-ene was purified by partial freezing, and had the following physical properties: m.p. 18°, n_D^{20} 1·4446. The National Bureau of Standards [2] gives: octadec-1-ene, m.p. 17·88°, n_D^{20} 1·4450. Buta-1 : 3-diene (which inspection in an infra-red spectrometer had shown to contain less than 2 per cent of any other C_4 isomer) was purified by distillation immediately before use.

Octadec-1-ene

To a stirred and cooled (−10°) solution of dinitrogen tetroxide (12 g, 0·13 moles) in dry diethyl ether (20 cc) were added dropwise over 65 minutes, 25·2 g (0·1 moles) of octadec-1-ene dissolved in ether (20 cc). After stirring for a further hour, the reaction mixture was worked up according to the general procedure of Levy and Scaife [3] to give 31·13 g of a yellowish-white, waxy solid, m.p. 32° to 34°. No water-soluble material was obtained.

By fractional crystallization from light petroleum (40° to 60°) the waxy solid was separated into two fractions; the less soluble fraction being obtained as colourless leaflets, m.p. 55°. After removal of the solvent from the mother liquors the petroleum-soluble fraction was recrystallized from ethanol (in which it was the less-soluble constituent) to give a yellowish-white powder, m.p. 37°. The substance melting at 55° was 1-*nitro-octadecan*-2-*ol* (II); yield 43 per cent (found: C, 68·4; H, 11·8; N, 4·5 per cent. $C_{18}H_{37}O_3N$ requires C, 68·5; H, 11·8; N, 4·4 per cent); whilst that melting at 37° appeared to be 1 : 2-dinitro-octadecane (I) contaminated with 1-nitro-octadec-1-ene (III); yield 49 per cent (found: C, 68·9; H, 11·0; N, 6·2 per cent. $C_{18}H_{36}O_4N_2$ requires C, 62·7; H, 10·5; N, 8·1 per cent and $C_{18}H_{35}O_2N$ requires C, 72·7; H, 11·9; N, 4·7 per cent).

From this latter analysis it would appear that partial loss of one nitro-group, presumably that originally on the penultimate carbon, had occurred during the separation of the dinitro-compound and although repeated attempts were made to obtain the pure dinitroparaffin by careful crystallization in the cold of further portions of the initial reaction product from various combinations of solvents (*e.g.*, methanol, ethanol, benzene, and light petroleum), no pure sample of 1 : 2-dinitro-octadecane could be obtained.

Characterization of 1-*Nitro-octadecan-2-ol*

Acetylation

1-Nitro-octadecan-2-ol (0·62 g) was acetylated by refluxing with acetyl chloride (5·5 cc). After cooling, the reaction mixture was poured into cold water and the precipitated 1-*nitro-octadecyl-2-acetate* (V) (0·65 g, 92 per cent) recrystallized from ethanol as a white powder, m.p. 44°. (Found : C, 67·8; H, 11·4 per cent. $C_{20}H_{39}O_4N$ requires C, 67·2; H, 11·0 per cent.) On treatment with anhydrous potassium carbonate (0·05 g) at 80° for 1 hr, the acetate (0·33 g) gave 1-nitro-octadec-1-ene (III) as a buff powder, m.p. 38° from ethanol; yield 84 per cent. (Found : C, 72·8; H, 11·8; N, 5·0 per cent. $C_{18}H_{35}O_2N$ requires C, 72·7; H, 11·9; N, 4·7 per cent.)

Reduction to 1-*Amino-octadecan-2-ol*

The nitro-alcohol (1·13 g), dissolved in glacial acetic acid (200 cc), was reduced at 20° and 87 atm of hydrogen over Adams's platinum catalyst (0·05 g) for 3 hr. After filtration the reduction solution was saturated with hydrogen chloride and the solvent removed under reduced pressure to leave 1·04 g (90 per cent) of 1-*amino-octadecan-2-ol hydrochloride* as fine, white, needle crystals, m.p. 98° to 99°, from ethanol. (Found : C, 66·9; H, 12·4; N, 4·4; Cl, 11·1 per cent. $C_{18}H_{39}ON$, HCl requires C, 67·1; H, 12·5; N, 4·4; Cl, 11·0 per cent.) Benzoylation of the hydrochloride gave 2-hydroxyoctadecyl benzamide as white, rosette crystals, m.p. 106·5°, from aqueous ethanol. (Found : C, 77·1; H, 11·1 per cent. $C_{25}H_{43}O_2N$ requires, C, 77·1; H, 11·1 per cent.)

Further characterization of the amino-alcohol hydrochloride was afforded by treatment of its hot aqueous solution with picric acid to yield the picrate, m.p. 120°, from ethanol, whilst treatment with warm 10 per cent aqueous alkali gave the free base itself (VI), recrystallized from ethanol as colourless leaflets, m.p. 78°.

Oxidation of 1-*Amino-octadecan-2-ol by Periodate*

Due to the limited solubility of the amino-alcohol hydrochloride in water it was not found possible to investigate its oxidation by sodium metaperiodate on a completely quantitative basis. However, by first dispersing the hydrochloride (0·3 m moles) in 25 cc of 0·2*M*-sodium hydrogen carbonate (the detergent action of the amino-alcohol making this feasible) it was possible to follow the oxidation in a fairly satisfactory manner using the normal procedure of Fleury and Lange.[4] Under these conditions (20° and pH 8) oxidation reached completion within 1 hr; 88 per cent of the theoretical periodate being consumed.

Ammonia and formaldehyde were present in the reaction product, the formaldehyde being isolated as its dimedone derivative in 36 per cent yield.[5]

Characterization of 1 : 2-*Dinitro-octadecane*

Reaction with Ammonia

The dinitro-compound (1 g) was dissolved in dry ether (30 cc) and dry ammonia passed into the solution until ammonium nitrite ceased to

be precipitated.[6] The precipitate was then filtered off, washed with ether, and the ethereal filtrate allowed to evaporate to leave 0·80 g (93 per cent) of 1-nitro-octadec-1-ene (III), which had after recrystallization from ethanol m.p. 38°.

Reduction to 1 : 2-*Diamino-octadecane*

The impure dinitroparaffin (0·6 g) was reduced as for the nitro-alcohol to give a residue of crude 1 : 2-diamino-octadecane dihydrochloride. This residue was then dissolved in a little hot alcohol, treated with activated charcoal, filtered, and the purified dihydrochloride (0·05 g, 8 per cent) precipitated as a white powder, m.p. 125° to 130°, by addition of ether to the alcoholic filtrate. Benzoylation of the dihydrochloride gave 1 : 2-di-(benzoylamino)-octadecane as colourless crystals, m.p. 134°, from ethanol. (Found: C, 77·4; H, 9·9; N, 5·9 per cent. $C_{32}H_{48}O_2N_2$ requires C, 78·0; H, 9·8; N, 5·7 per cent.)

Buta-1 : 3-*diene*

1 : 1 *Mole Addition*

To a solution of buta-1 : 3-diene (11·5 g, 0·21 moles) in dry diethyl ether (25 cc) stirred to −30° was added dropwise, during 1½ hr, a cooled solution of tetroxide (18·4 g, 0·2 moles) in ether (25 cc). After stirring for a further 1½ hr, the cooled (−10°) reaction mixture, from which a yellow, crystalline solid had separated, was treated with water (50 cc) and vigorously stirred. The crystalline product (3·71 g) was then filtered off and the filtrate worked up by the general procedure of Levy and Scaife[3] to give 10·7 g of a dark-brown, unsaturated, water-insoluble oil and 12·5 g of a brown, unsaturated, water-soluble liquid.

On standing overnight the former of these liquid products deposited 2·05 g of a brown, amorphous powder, a further 3·67 g of which were obtained by trituration of the oily filtrate with ether. Ebullioscopic molecular-weight determinations on this amorphous material showed it to be a polymer of average molecular weight 550. Attempted distillation of the water-soluble product (2·9 g) under reduced pressure, immediately upon its isolation, was unsuccessful; violent decomposition occurring at the boiling temperature (45°/2 mm) to leave a tarry residue. Similarly, the remainder of this product (possibly a nitrobutenol) on standing for 2 days decomposed with gas evolution to leave an intractable tar. The crystalline product, which on standing had slowly turned brown, was recrystallized from ethanol to give the unstable 1 : 4-dinitrobut-2-ene[7] (VII) as needle crystals, m.p. 58° to 60° (decomp); yield 12·5 per cent. (Found: C, 33·6; H, 4·1; N, 21·4 per cent. $C_4H_6O_4N_2$ requires C, 32·9; H, 4·1; N, 19·2 per cent.)

2 : 1 *Mole Addition*

Buta-1 : 3-diene (5·4 g, 0·1 moles) dissolved in dry diethyl ether (15 cc) and cooled in a drikold-bath was added dropwise over ½ hr to a stirred solution of tetroxide (26·3 g, 0·29 moles) in ether (30 cc) at −30°. After stirring the reaction mixture for a further hour, during which time the temperature was allowed to rise to +3°, the solvent and excess tetroxide

were removed at the pump using a carbon dioxide capillary leak, and the cooled residual material, from which yellow crystals had separated, worked up as in the 1 : 1 mole addition to give 2·12 g (14·5 per cent) of 1 : 4-dinitrobut-2-ene (VII), together with 14·9 g of a saturated, water-soluble, amber liquid and 1·4 g of a brown, water-insoluble oil.

Trituration of this latter product with ether afforded a brown, amorphous powder similar to that obtained from the 1 : 1 mole addition, whilst attempted distillation of the water-soluble product (1·1 g) at 0·5 mm pressure resulted in its rapid decomposition at the boiling temperature (50°/0·5 mm) to leave a tarry residue. Similarly, attempts to characterize the water-soluble product (possibly a polynitrobutanol) by catalytic reduction in glacial acetic acid over Adams's platinum catalyst, and by esterification with 3 : 5-dinitrobenzoyl chloride, were also without success, no identifiable products being obtained.

Characterization of 1 : 4-*Dinitrobut-2-ene*

Reduction to 1 : 4-*Diaminobutane*

Reduction of the 1 : 4-dinitrobut-2-ene (0·5 g) was carried out as for that of 1 : 2-dinitro-octadecane and gave 0·16 g (29 per cent) of crude 1 : 4-diaminobutane dihydrochloride. After purification by precipitation with ether from its alcoholic solution, the diamine hydrochloride was characterized by formation of its dipicrate, m.p. 250° (decomp), from aqueous acetone, and dibenzoyl derivative, m.p. 178°, from ethanol.

All temperatures recorded are uncorrected, and analyses were carried out by Drs Weiler and Strauss of Oxford.

Acknowledgments

The authors' thanks are due to the Institute of Petroleum for financial assistance through the Hydrocarbon Research Committee; to Imperial Chemical Industries Ltd. for an I.C.I. Fellowship to one of them (C. R. P.), and to Professor F. H. Garner, O.B.E., for helpful advice.

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ERRATUM

"Some Aspects of Field Operations in Kuwait"

Page 411, line 2. *For* "but now they are at 30°" *read* "but in Kuwait they are at 1 in 30."

OBITUARIES

DANIEL GEORGE PIDGEON, M.B.E.

We regret to announce the death, which occurred quite suddenly on 23 July 1952 at the age of forty-nine, of Daniel George Pidgeon, Associate Member of the Institute since 1932, having been a Student Member from 1927.

In 1925 he joined the Anglo-Iranian Oil Company straight from school, and was employed at their Research Station, Sunbury-on-Thames. Whilst there he took his B.Sc. degree as an external student of London University, and later his F.R.I.C.

In 1929 he went to Persia as a junior chemist, and served out there with increasing responsibilities in the chemical engineering field until 1940, when he joined H.M. Forces and was commissioned in the Royal Army Service Corps. He saw service mostly in the Middle East, and latterly, with the rank of Major, commanded the first Mobile Petrol Laboratory to be put into active service with the Army. First in the Western Desert, and then up through Italy as the advance continued, he was responsible primarily for the assurance of the quality of all petroleum products used both by the Army and by the R.A.F. In addition, he supervised the sampling and testing of captured enemy petroleum products for use by our own forces. The work he carried out in the Middle East Command proved to be of great value, and the outstanding services which he rendered were duly recognized in the award of M.B.E.

After demobilization in 1945 he rejoined the staff of Sunbury Research Station as a senior chemist, and in 1947 was transferred to the AIOC London Office, where he became head of the Operations Group under the Chief Process Engineer.

To his wide circle of friends with whom he was associated both in the Army and civilian life, the news of his untimely death has come as a profound shock, and their deep sympathy is extended to his widow and three children.

R. E. A.

H. N. L. C. E. C. DE WILDE

The late Hendrick Nicolaas Lodewijk Christoffel Eliza Carel de Wilde was born in London on 27 June 1891. He spent his early years in South Africa, and in April 1914 entered the service of Astra Romana in Roumania. From 1916 to 1922 he was employed by N.V. de Bataafsche Petroleum Maatschappij as a driller at Tjepu in Indonesia, after which he spent about eighteen months in the United States of America, principally to study the rotary drilling technique employed in the Californian fields.

At the end of 1923 de Wilde returned to Indonesia and, in Pangkalan Brandan and Tjepu, he occupied successively the positions of chief driller, assistant field superintendent, and acting field superintendent.

In August 1927 he left the company and returned to England, where he entered Birmingham University and studied engineering, taking his degree as a Bachelor of Science, followed by that of Master of Science in 1932.

In mid-1930 he re-entered the service of N.V. de Bataafsche Petroleum Maatschappij as an equipment engineer in their Production Department in The Hague. In December 1939 he was transferred to the Shell Petroleum Company's head office in London as technical adviser on oilfield drilling and production equipment to their Export Department. He returned again to The Hague between 1942 and 1946, but came back to Export Department in London in May of the latter year to take complete charge of the purchase of all the British made drilling and production equipment used by the Royal Dutch/Shell Group. Here he made the remainder of his career.

During this period an outstandingly important part of his work lay in the development of suitable supplies of this equipment made in Britain. To many manufacturers this was an entirely new type of manufacture, in connexion with which they had little or no past experience to draw upon in producing a quality of equipment which would compare favourably in its performance with the well-established types of foreign origin which the oil industry had been accustomed to use. Henry (as he was universally known to his many friends both amongst oil men and manufacturers) flung himself whole-heartedly into this work, and was happiest when placing his great fund of technical and practical knowledge at the disposal of manufacturers.

This he did most unstintingly, in spite of constant ill-health. The fact that by far the greater part of the drilling and production equipment now used by the Shell Group is produced in the United Kingdom is evidence enough of what he did, whilst by introducing the fishing magnet he was personally responsible for carrying fishing technique a step in advance of the best yet developed elsewhere.

Mr de Wilde joined the Institute in 1927 and was elected a Fellow in 1939. In 1947 he was elected to the Council and served also on the Engineering and the Publications committees.

His technical interests ranged over other fields beside that of his work. During the war he developed a method for converting the mortars issued to the Home Guard so that they could be used for indirect fire and made the slide rules needed for calculating this with his own hands. Hard-facing materials came in for attention as well as improvements in the design of coal-cutter bits, whilst all the time he delighted in explaining the technical work of the oil industry to non-technical staff of an inquiring turn of mind.

Through steadily failing health, borne with great fortitude, he had to give up his work early in 1951 for a period of hospital treatment. Although he returned home in better health, the improvement was, unfortunately, not maintained, and he passed away on 28 August 1952 at the age of sixty-one. His loss will be felt by many, who extend their deepest sympathy to his widow and daughter.

FREDERICK CHARLES BAKER

It is with regret that we record the death on the 8 August 1952 of F. C. Baker, a Member of the Institute since 1928. A well-known figure in the lubricating oil trade, with which he had been connected for over forty years; he had taken an active part in its various associations as a member and past chairman of the Liverpool Lubricating Oil & Grease Association, and in this connexion represented Liverpool and Southwest Lancashire on the Oil Distributors Emergency Council during the war years.

In 1931, Mr Baker founded, with Harry Essler Kessen the Exchange Oil Co. Ltd., of which he was managing director until his death.

A keen and active social worker, he represented Bebington Ward on the Bebington U.D.C. from 1934 to 1944, serving on the Finance and Parks Committees, was Chairman of the Public Libraries, and represented the Council on the Liverpool Port Health Authority. He was a member of the West Cheshire Water Board for twenty years, a Member of the Burial Board of Bebington Cemetery, and an administrator of the Bebington Lands Foundation Trust.

From 1942 to 1949 he was Bebington representative on the Cheshire County Council; during this time he was County Council representative and chairman of Clatterbridge Hospital. With the introduction of the National Health Service, Mr Baker was retained as chairman of the newly formed Central Wirral Hospital Management Committee, and only retired from this position early in 1952, owing to ill health.

During the first world war, Mr Baker served in France with the Army Service Corps. He was wounded in 1914 but, despite the continued handicap of this disability, he was always a cheery and enthusiastic companion; this was manifest during his prolonged illness.

Mr Baker leaves a widow, two sons, two daughters, the eldest son having been in business with his father since 1935.

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Oilfield Exploration and Exploitation

Geology

2546. Oil finding. F. A. Morgan. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (7), 1297.—In his address to the 37th annual meeting of the American Association of Petroleum Geologists the author mentioned that approximately two-thirds of the Association's members are engaged to this end, or are in Federal and State surveys.

Throughout the years there had been periodic scares of shortages in oil production, but in spite of the fact that one chief geologist of the U.S. Geological Survey predicted an early peak of the output of the U.S. and that consequently relief must come from other foreign fields and from production by distillation from shale oil (a statement frequently heard to-day) American oil production had now increased to 2100 million brl a year. E. N. T.

2547. How little we know. D. C. Ion. *Inst. Petrol. Rev.*, 1952, **6**, 329; *Petrol. Times*, 25.7.52, **56**, 613; *Oil Forum*, 1952, **7**, 267.—A recent talk to the Oil Industries Club during which the three principal approaches to the problems of the origin of petroleum on botanical, bacteriological, and radioactivity lines were briefly surveyed. The importance of furthering studies in all possible ways was stressed as a matter of vital concern to both oil producers and manufacturers. J. H. P.

2548. Paleofacies, the geologist's new tool. T. H. Philpott. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (7), 1305.—A better understanding of the biozone and its environment

would lead to a better knowledge of the relationship of palæontology and oil exploration.

It has become increasingly apparent that porous limestones and sand lenses, associated with structural terraces and noses rather than faults and anticlines, will control the important petroleum reservoirs of the future. Except in certain limited areas, most palæontological work consists of the recognition of a single genus or species, or sometimes general assemblages, but within this field problems frequently arise because the geologist does not appreciate palæontological data.

The geologist usually gets his information in the form of reports or publications, and if the information fits the general conditions it is used to support pre-existing correlations, but when there is no support it is questioned.

A palæontologist is first a good geologist and second a specialist in cyrtopalæontology; he should therefore be a fully-fledged member of the oil exploration team. E. N. T.

2549. Micro-palaeontology of the non-marine Rhaetic. C. A. Wicher. *Erdöl u. Kohle*, 1951, **4**, 755–60.—The passage from non-marine Rhaetic to Lias can be readily distinguished by means of megaspores. In the Lias there are but two forms, whereas in the Rhaetic there may be as many as twelve to fifteen. Furthermore, several of the Upper Rhaetic forms are distinguished by circumferential bulges which have not been observed so far in any forms from other formations. The strongest marine element is in the Mid Rhaetic, the fauna of which is stunted and impoverished and characterized by the foraminifera *Protaina* and *Ammodiscus* and small forms of ostracods. The Lower Rhaetic fauna is composed exclusively of ostracods. S. E. C.

2550. Modern optical methods for heavy mineral determination. H. Schumann. *Erdöl u. Kohle*, 1951, **4**, 684–7.—Work on sediments depends on correct mineral identifications, and improvements in methods are discussed. These include refractive index determinations by gelatin-coated slides and by Wilke's stage refractometer, the use of combination-plate compensators, the determination of dispersion, and the use of the universal stage. S. E. C.

2551. Weathering of heavy minerals in sediments. I. Description and occurrence. R. Weyl. *Erdöl u. Kohle*, 1952, **5**, 29–33.—In soils and weathered zones the weathering of heavy minerals is associated especially with non-calcareous material, and is indicated by etching and loss of the less stable minerals. Its occurrence can be established with certainty only when the fresh source material is known. A consideration of numerous examples suggests that the weathering of heavy minerals is of importance in marine sediments only when they are unconsolidated, lime-free, and subject to the action of ground waters after deposition. The action therefore is due to terrestrial agencies, and marine conditions appear to conserve the mineral content. In terrestrial sediments the effect is found in the enclosed parts of deeply weathered sections as well as in deposits subjected to subsequent weathering. Fluviatile gravels and sands are especially liable, particularly when deepening of the river bed transfers them from the sedimentation zone to that of transport. Critical conditions can arise in coastal areas where marine and fluviatile beds alternate in the profile. It is necessary therefore to take weathering into account in the interpretation of mineral associations. S. E. C.

2552. Weathering of heavy minerals in sediments. II. Facies and stratigraphical significance. Tj. H. v. Andel. *Erdöl u. Kohle*, 1952, **5**, 100–4.—There are differences of opinion on the extent of sorting by weathering but not on the principle. The criteria used for its recognition can be misleading, and the characters observed may be due sometimes to other causes. A single cycle from source to deposition is considered, and it is concluded that most of the known occurrences of surface weathering are limited to coarse, permeable rocks which lie in terraces high above the water table. In addition to sub-aerial weathering, Pettijohn suggests that minerals disappear due to intra-stratal solution, and so explains the striking decrease in richness of assemblage with increase in age of the beds. This theory also is subject to many exceptions. It is concluded that although the overall development is largely determined by weathering, the mineral associations are only seldom controlled in this way and by interstratal solution, and usually they are a reliable indication of origin and conditions of deposition. S. E. C.

2553. Spore diagnosis in stratigraphy. R. Potonié. *Erdöl u. Kohle*, 1952, **5**, 145–8.—In 1934 the author established that the composition of spore associations in coal is dependent on the particular layer in the seam from which they come. When there is a repetition of petrographically similar fine layers the associations characterizing those layers is repeated over a considerable stratigraphic range. Spore associations therefore depend on facies, and the truth of this is not confined to coal. In many there are sub-autochthonous as well as allocthonous elements which are recognized, more or less, by plant-sociological, ecological, and petrological considerations and which enable conclusions to be drawn on the plant associations proper to the facies. A greater number of associations can be separated by spores than by mega-fossils.

S. E. C.

2554. Oil prospects in south central portion of Salina Basin. R. L. Gilmore. *Oil Gas J.*, 2.6.52, **51** (4), 91.—Surface indications plus subsurface geology justify expectations that oil and gas will be found in commercial quantities in the south central portion of the Salina Basin. The necessary source and reservoir beds are present. Drilling operations are to begin soon at a number of locations. J. C. M. T.

2555. Doswell discovery enhances oil possibilities of San Juan Basin. O. J. Lilly. *Oil Gas J.*, 2.6.52, **51** (4), 102.—Doswell field lies near the centre of the San Juan Basin, New Mexico. The Discovery well, completed July 1951, produced 404 b.d. of 50·2° API grav oil from the Tocito sandstone at 6622 to 6638 ft. This sandstone is of Upper Cretaceous age, has porosities of 5 to 20% and permeabilities of 2 to 622 mD. The cumulative production of the field to Jan. 1952 was 64,054 brl, with no production of water. The field appears to be a stratigraphic trap with no structural uplift.

Oil and gas shows have been found at Kutz Canyon and West Kutz Canyon gas fields, and as the Tocito sandstone thickens in a west and southwest direction from Doswell it is thought that this area may prove to be the largest oil and gas producer in the San Juan Basin. J. C. M. T.

2556. Uinta Basin. V. E. Farmer, Jr. *Oil Gas J.*, 26.5.52, **51** (3), 199.—The Tertiary portion of the Uinta Basin occupies 8000 sq. miles in the extreme northeast of Utah, and its thickness is probably over 15,000 ft in the deep northern portion. It is a typical intermontane basin with steep northern flank with beds of Oligocene to Palæocene age. The first discovery was in 1949 at Roosevelt. After acid treatment the well flowed 1633 b.d. of 33° API oil from lower Green River formation at 9200 ft. The reservoir appears to be a fractured lacustrine shale. Pour point of the oil is abnormally high—between 85° and 100°. Other fields were discovered in 1951 at Duchesne and Red Wash. J. C. M. T.

2557. The general and economic geology of Trinidad, B.W.I. Pt II. H. H. Suter. *Colon. Geol. min. Resour.*, 1951, **2**, 271–307.—In this part the rocks of Trinidad are considered under six main headings, one of which is hydrocarbon rocks and minerals.

G. S.

2558. Petroleum geology of South America. I. The Upper Amazon Basin. J. E. Rassmuss. *Erdöl u. Kohle*, 1951, **4**, 611–15.—The Upper Amazon Basin occupies almost one-half of Peru, lies above the 1000-m contour, and is mostly covered by forest. Since the war photo-geologic studies of the greater part have been made by oil companies such as International Petroleum, Shell, Socony-Vacuum, and a pipeline from the Marañon to the Pacific coast has been plotted, but large scale development has been held up pending a new Peruvian oil law. The economic significance of the area lies in the fact that it is one of the few great potential oil regions of the west coast of America and is far from all danger spots of the present world.

The geological situation of the area between the Cordillera and the Brazilian Shield is reminiscent of that of the new Canadian fields, as is also the occurrence of Permian reef limestones beneath the petroliferous Cretaceous. Stratigraphically it is part of the eastern edge of the Mesozoic Andean geosyncline, and the alternation of marine beds with thick litorial to continental sandstones offers favourable conditions for the formation and accumulation of oil. Stratigraphy and tectonics are described in some detail.

Oil shows are common throughout the region, but so far the only producing field is Ganso Azul, in which nine wells were drilled to a depth of 300 to 400 m, except the first, which was carried to 955 m as a deep test. Production is from Lower Cretaceous sandstone, and the six producing wells have a potential of 9000 b.d. but are restricted to 400 b.d. because there is so far no outlet for the oil apart from local needs. The deep test found lower oil sands in the Cretaceous but no oil in the Permian reef limestone. Other structures have been drilled, so far without results, but the total amount of drilling in such a huge area is so small that the Ganso Azul success gives occasion for optimistic predictions. S. E. C.

2559. South German Tertiary stratigraphy. H. Bartenstein. *Erdöl u.Kohle*, 1951, **4**, 679–83.—Increased drilling in South Germany has made very necessary the revision, by modern methods, of Tertiary stratigraphy, and there is an especial need for micropalæontological research aimed at subdividing the larger divisions established on macropalæontological grounds. Proceedings of the 65th Conference on Micropalæontology and Stratigraphy held in Munich in May 1951 are reported, and the Tertiary of the eastern Alps and the Flysche nappe zone and in the Helvetian nappe zone, the subsurface Eocene and Palæocene, the Oligocene and the Miocene of the Molasse basin, and the work on the Tertiary in neighbouring countries are dealt with. The bulk of the discussion relates to the Molasse basin. S. E. C.

2560. Micropalaeontology of the Tertiary of the Rhine Valley in Baden. H. Weber. *Erdöl u. Kohle*, 1951, **4**, 543–9.—The Rupelian at Wiesloch near Heidelberg can be divided into the Meletta Beds, Fish Shales, Foraminiferal Marls, Basal Beds, and Pechelbronn Beds. These have a rich microfauna, by the aid of which a very detailed subdivision has been made. The variations in the fauna parallel changes in the sediments and throw light on conditions of sedimentation and environment. The Lower Rupelian was deposited in a basin in which there was increasing toxicity due to hydrogen sulphide. The fauna and sediments of the Upper Rupelian in contrast point to a gradual freshening of the basin. S. E. C.

Geophysics and Geochemical Prospecting

2561. Geophysical exploration comes of age. S. Hammer. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (7), 1318. (*Presidential address to the Soc. Exploration Geophysicists.*)—A review of events of the past and present, and the future prospects in the field of geophysical exploration.

At the present geophysical exploration and activity throughout the world has reached an all-time high level: 791 seismic crews, an increase of more than 20% over 1950; and 123 gravity crews, showing an increase of 12% over the past year. The improvement resulting from the combination of geology and geophysics in exploration has amounted to a saving of twenty-five dry holes per discovery compared with a wasteful twenty-nine under random drilling. E. N. T.

2562. The effect of errors on dip and depth estimation in reflection seismic surveys. L. Krousky. *Erdöl u. Kohle*, 1952, **5**, 210.—Errors in measured quantities, such as times and geophone separations, enter into the calculation of dip and depth of a reflection element. The influence of these errors on the final calculations is the subject of a mathematical analysis. S. E. C.

2563. New refraction seismic work on salt stocks in N.W. Germany. H. v. Helms. *Erdöl u. Kohle*, 1951, **4**, 615–20.—The author's purpose is to show how the form of a salt stock can be ascertained from time–distance curves derived from refraction seismic surveys. The work is based on a whole series of refraction surveys on salt stocks and structures made in Northwest Germany in recent years. For unequivocal results it is essential to observe as many lines as possible on straight line profiles by shifting the shot point in the direction of the salt and to supplement this by also moving in the reverse direction. The determination of true velocities, and consequently the depth and inclination of the carrier horizon, must be found by shooting in both directions in the foreland and the depth, inclination and location of the top edge of the salt are ascertained from time–distance curves over the salt surface. Detailed diagrams and discussions of various types of structure are given. S. E. C.

2564. Refraction seismic surveys on salt stocks in the Hamburg Depression. H. v. Helms. *Erdöl u. Kohle*, 1952, **5**, 77–80.—The problem of the behaviour of the Upper Cretaceous on the flanks of the Quickborn, Schnelsen, and Siek salt stocks to the north of the Elbe has become important since the development of the Reitbrook and Meckelfeld fields. Reflection seismic methods were used on the Siek–Witzhave structure and refraction on the Quickborn and Schnelsen salt stocks and also for the area between them and the Siek salt stock. The refraction work is discussed in the present article, and it is concluded that the method can be successfully applied in regions of thick Tertiary cover, where the hard Upper Cretaceous horizon is at considerable depths—2000 m or more. S. E. C.

2565. Seismic investigations in the Peissenberg coal mine. H. Reich. *Erdöl u. Kohle*, 1951, **4**, 538–43.—Velocity measurements are of the greatest importance in reflection seismic work, but the opportunity to make them below ground in mines in prospective oil territory is rare. This paper discusses work done in the Peissenberg coal mine in Upper Bavaria at a depth of 650 m. The level in which most of the observations were made is cut by the Sulzer fault, which throws Molasse against Promberg Sandstone. Velocities in these same beds were also measured in the Tölz I borehole, which again is in a fault zone. It was found that longitudinal velocities in undisturbed Molasse were 3200 m/sec, compared with 3600 m/sec in the Promberg Sandstone, but that with approach to the fault zone they increased to 3560 and 4700 m/sec respectively. The effect of the fault therefore is the reverse of disruption, and probably it has hardened the rocks by pressure and deposition of calcareous cement in cracks, etc. It is noteworthy that in addition to the normal longitudinal waves, transverse waves could be measured with velocities of 1800 m/sec in the Molasse and 2150 m/sec in the Promberg Sandstone. S. E. C.

Drilling

2566. Latest developments and achievements of directional drilling in the exploitation of oilfields. H. J. Eastman. *Proc. 3rd World Petrol. Congr.*, 1951, **2**, 89–109.—Recent techniques have vastly increased the applications of directional drilling, and penetration rates in directional wells now approximate average rates for straight-hole drilling; it is anticipated that future developments will be towards the simplification of operations.

Applications of controlled directional drilling include: deflecting from accessible to inaccessible locations; deflecting around and under salt dome overhangs; deflecting relief wells to control wild wells; deflecting several wells from one location; and side-tracking obstructions.

The latest types of deflecting tools can drill a full gauge hole, thus eliminating the need for secondary reaming. The use of a large-size bit is an advantage in side-tracking, in increasing drilling speed, and improving hole conditions. The latest tool, the Driftmaster, is a self-orienting full gauge knuckle joint which is oriented by a mechanism actuated by gravity. In use, a weight is applied to the pilot bit, the gravitational element is released, and the tool is automatically positioned in relation to the bore hole direction; the tool is then raised and the drill pipe rotated to point the bit in the required direction.

The pipe alignment method of orienting is still used for shallow depths, but is being replaced by the bottom hole orientation method, which is rapid and very accurate. The Eastman method for bottom hole orientation uses the direction of the well bore, direction of tool face, and the direction of a magnetic field having a known angular relationship to the tool face.

In planning a directional drilling programme the penetrability of formations should be determined, and the depth at which deflection is started will greatly affect the overall well cost. If a fairly high angle in the deflected section is used there will normally be saving in rig time and other costs, since the directional work can be started deeper. Most economic drilling is at drift angles of 15° to 45°, and the best practice is to increase the angle slowly.

The surface spacing of wells must also be considered in relation to the bottom hole subsurface spacing, and the wells must be planned to take advantage of multiple zone completions, possible deepening, and perforating at an upper level.

Outstanding applications of directional drilling are described; these include offshore work off the California coast, Lake Maracaibo, and the German North Sea; the drilling of relief wells to control wild wells; and obtaining production from zones beneath industrial and residential areas. C. A. F.

2567. A drillability classification of geological formation. A. L. Head. *Proc. 3rd World Petrol. Congr.*, 1951, **2**, 42–55.—A classification of geological formations based on the relative efficiency with which they can be drilled with a small rolling-cutter type test bit is given. This classification is consistent with field drilling practices.

The efficiency with which a formation can be drilled is a function of the rate of penetration of the bit, which is controlled by the following factors: type of formation, type of bit, weight on bit, rotational speed, hydraulic action, size of hole, and efficiency of personnel and equipment. The type of formation is the only factor truly independent of control.

The test bit used to determine the drillability classification was designed to facilitate the replacement of the cutters after each test, and the dia of the drills was made small enough to drill into core samples of common sizes. The bit was connected to the tailstock of a lathe, the rock samples being held in the chuck.

The factors which could be measured accurately were: rotational speed, bit thrust, depth drilled, and time; the drillability classification was based on the time interval necessary to drill a constant depth of $\frac{1}{8}$ inch in each of fifteen samples at a constant rotational speed of 110 r.p.m. No relationship between hardness and drillability was found.

The classification provides a means of determining the formation which each type of bit will drill most economically with respect to other types.

Photographs of the test bit and the drilling equipment used are included, and five references are given. C. A. F.

2568. Richfield's servicing unit. D. H. Stormont. *Oil Gas J.*, 9.6.52, **51** (5), 76.—Describes a self-propelled work-over rig weighing 28 tons, put in operation in the Cuyama Valley field by Richfield Oil Corpn. For use on 6500-ft wells and capable of hoisting 9000 ft of wet 2$\frac{1}{2}$-inch tubing, it has a 90-ft, 70-ton capacity derrick. It is capable of road speeds up to 40 m.p.h., and will take a 25% gradient at 3 m.p.h. J. C. M. T.

2569. Progress in drilling and well servicing plant. A. Vierling. *Erdöl u. Kohle*, 1952, **5**, 91–7.—Recent developments, particularly in German equipment, are reviewed. Telescopic masts have been introduced for truck-mounted rigs used for deeper core drilling. The large folding masts for production drilling appear to have reached their limit with crown block loads of 200 to 250 tons and heights of 40 m, and for heavier work a return to earlier types, but with the benefits of modern developments in design and material, must be considered. There are improved designs also for substructures. Hydraulic torque converters for draw-works and rotary table are becoming more and more common, and it is shown how they could be used to give some measure of automatic control. Indicating and recording instruments assist in drilling. Limitation in the types of engine used improves the replacements and spares position. Specially designed tracks are fitted to tractors carrying winches for general field work. Engines and hoists are also mounted on skids for use when a vehicular mounting is not suitable. The conventional deep well pump is improved by modern materials and methods of construction and handling. A new, long-stroke pump is combined with a folding mast which carries both the driving gear for the pump and servicing equipment for the well. S. E. C.

2570. Design of drilling and production masts. A. Vierling and E. Bahke. *Erdöl u. Kohle*, 1952, **5**, 215–22.—At this stage in the development of portable masts an agreed basis for design calculations is desirable, the more so as the rules for stationary derricks no longer suffice. The present position is shown by taking a folding mast with crown block loading of 210 tons as an example. From a consideration of design and economy and the basic factors, such as assumed loading, wind loading, hook loads, safety factors, which are laid down in German Standards DIN 4111 and DIN 120 and API

Specifications for Standard Rigs and Derricks, proposals for new specifications for portable masts are developed. It is recommended that test loading be used to confirm calculated limits, and an example is worked out to illustrate the method. S. E. C.

2571. Problems of wear in drilling. W. Späth. *Erdöl u. Kohle*, 1952, **5**, 159–61.—A knowledge of the various factors determining wear is necessary if drilling is to be carried out economically. Accordingly, the relationship between rate of wear and life of equipment, the rate of rotation and the effect of wt are discussed. It is shown that with low loading the number of bits used per thousand m of drilling is little affected by rate of rotation, whereas with heavy loading the number of bits used increases rapidly with increasing rotary speeds. S. E. C.

2572. Systematic analysis of drilling operations. C. H. Biedendieck. *Erdöl u. Kohle*, 1952, **5**, 299–303.—A comprehension of all details is of paramount importance for the efficient and economic management of drilling. This includes not only personal supervision, which is predominantly technical, but also an understanding of performance and costs. The position of performance statistics in the complete picture is outlined and the various processes in the sinking of a well defined. These are used in the construction of charts which summarize equipment and drilling performance. S. E. C.

2573. Light-weight construction in drilling and production equipment. E. Bahke. *Erdöl u. Kohle*, 1952, **5**, 151–9.—The object of light-weight constructional methods is to reduce weight whilst maintaining static and dynamic strength. To achieve these ends the greatest possible application is made of recent advances and knowledge of constructional materials, of the theoretical basis of design and calculations, and of shapes and forms. The application of these methods to oilfield equipment is discussed. S. E. C.

2574. Drilling and producing oil and gas in the Gulf of Mexico. L. S. McCaslin. *Proc. 3rd World Petrol. Congr.*, 1951, **2**, 169–92.—An estimated $200 million has been spent in the current search for new reserves in the Continental Shelf area of the Gulf of Mexico.

The drilling methods which have been used in the area are described; these include the floating tender–platform combination, the self-contained drilling platform, and the "stabilized sea drill," which has been designed for rapid site-to-site moves.

There are two main problems in methods of production: location of a site for well equipment and developing an economical method of transporting the produced oil and gas to the shore.

Photographs and diagrams of offshore equipment and fifty-seven references are included. C. A. F.

2575. Internal hydrostatic pressure testing as a measure of the performance values of oil well casing and tubing. H. G. Texter. *Proc. 3rd World Petrol. Congr.*, 1951, **2**, 1–23.—Acceptable methods of determining whether any given lengths of casing or tubing can withstand the forces to which they will be subjected in oil well service are discussed, and it is shown that high internal pressure testing is the most reliable and least expensive single method of checking performance values.

Casing and tubing in wells are distorted or collapse due to three main mechanical forces: tension, due to longitudinal loading; collapse, due to unbalanced external pressure; and bursting, due to unbalanced internal pressure. Less important factors are: buckling, wear, erosion, thread breaks, leakage, and corrosion.

It is claimed that the API casing and tubing specifications do not ensure that the products can withstand field service in a well, only one test, the Mill inspection Hydrostatic Test, giving a direct proof of quality.

It is recommended that each length should be proof tested, by internal pressure to 80% of the minimum yield strength.

Photographs of pipe defects and four references are included. C. A. F.

2576. Some considerations of the interchangability of conical threads as specified by the American Petroleum Institute. G. Dommain. *Proc. 3rd World Petrol. Congr.*, 1951, **2**, 235–48.—Three systems of successive gauges form the basis for the interchangeability

of conical threads, and in particular tool-joint threads. These are : the Grand Master Gauge, the Master Gauge, and the Working Gauge : their dimensions and the conditions for their use are prescribed by the API.

By means of a simple formula it is possible to define the quantitative incidence of the various tolerances on the value of the measurements made by these systems, and their limits of applicability can be calculated.

Five references. C. A. F.

2577. A study of the relative applicability of retrievable and retainer-type production packers to specific oil well problems. B. E. Mater. *Proc. 3rd World Petrol. Congr.*, 1951, **2**, 250–63.—Production packers of the retrievable and retainer-type are described and their application to special problems discussed in order to determine which type should be used for specific purposes.

The retrievable packer is part of the tubing or production string, and requires either continuous set-down tubing weight or continuous up-strain to effect and maintain a pack-off. The material of this type is not drillable.

Retainer-type packers are part of the casing, and can only be removed by destruction, since they utilize two sets of opposed slips that cannot be retracted after setting.

Fourteen applications of production packers are described, and include : testing of formations for available and economic production, isolating one or more zones, selective acidizing, and multi-zone production. The retainer-type has unique application as a squeeze tool or bridge plug.

The choice between the two types for any specific application can be based on the extent to which the design of the tool satisfies the basic requirements of the problem, the presence of unusual well conditions, packer removal considerations, and the purchase, installation, and maintenance costs.

In selecting the retainer-type the following must be considered : the ability to permit tubing removal with simultaneous isolation of the sub-packer zone, whether the pack-off is independent of the tubing weight and/or tension, and the versatility of the changeover flow accessory.

Selection of the retrievable-type must generally be based on the relative value or importance of retrievability. C. A. F.

2578. Concerning the problem of sensitivity in the power control of drilling outfits with hydraulic torque converter. W. Schultz. *Proc. 3rd World Petrol. Congr.*, 1951, **2**, 74–88.—Until recently, developments in the design of hydraulic converters have been restricted to various adjustments to the characteristic curve of the secondary torque and the improvement of its general efficiency by such features as free-running blade systems and by-pass couplings. Current research is towards improving the control of secondary factors important in the hydraulic transmissions and drawworks.

The control of hydraulic torque converters, which is through the primary power input, can be influenced in various ways ; the standard practice of varying the speed of the diesel causes a reduced power output, the unit having a low speed of response. A hydraulic torque converter which provides a considerable reduction in the control route and which permits the diesel to continue running at its normal speed will give greater flexibility in service. C. A. F.

2579. Meeting the problem of sub-surface formation slippage in the drilling and production of oil wells. G. M. Anderson. *Proc. 3rd World Petrol. Congr.*, 1951, **2**, 162–8.—Earth movements in relation to the drilling and production of oil wells are outlined, and the specific problem of slight, deep movements due to low intensity tremors in the Long Beach Harbour area of California is described in detail.

Formation slippage can be divided into three types : cataclysmic, due to movements whose epicentre is close to the area affected ; gradual movements ; and weak movements due to low intensity tremors.

By using a " bell hole " scraping programme, details of which are given, danger to wells due to these low intensity tremors is minimized ; the technique, which is cheap and simple, is now being used as routine. C. A. F.

2580. An introduction to the hydraulic long stroke pumping unit for pumping problem wells. D. M. Jones. *Proc. 3rd World Petrol. Congr.*, 1951, **2**, 264–77.—In using

standard rig fronts and pumping units for pumping deep wells over 8000 ft with sucker rods it was found that due to stretch loss in rods there was too little net plunger stroke to obtain the required production. To attempt to overcome this, lighter units were run at max stroke length and gear-boxes became overloaded; mechanical unit and sucker rod failures became frequent. A new device, the hydraulic long-stroke unit, was therefore developed, and this permits a longer stroke than is possible with the beam pumper. Present units provide up to 30 ft of stroke and a total polished rod travel of approx 350 f.p.m. Conventional beam units travel 35 c.p.m. with a 5-ft stroke. Seven references. C. A. F.

2581. Chain drives in the oil industry. A. Scherfig. *Erdöl u. Kohle*, 1951, **4**, 697–8.—When a second slush pump is provided it generally requires an independent drive. This commonly is either flat or V-belt, but the low rate of rotation of the pump and the relatively low reduction gearing in the pump demand very large dia sheaves. The substitution of Westinghouse chain drive overcomes the disadvantages occasioned by large size and wt. Its application to rotary table drive is also mentioned. S. E. C.

2582. Friction clutches for oilwell drilling equipment. A. Hilb. *Erdöl u. Kohle*, 1951, **4**, 693–7.—The various types of friction clutches used in rotary drilling operations are briefly described. S. E. C.

2583. Science and technique in Soviet Union (Monthly review)—Drilling equipment for small diameter coring. R. Piatkiewicz. *Nafta*, 1951, **7**, 215–22; 252–8. (From "*Boorovoye Dyelo*," by Vozdvizhenski and Volkov.)—Detailed description and drawings of four types of drilling equipment designated as KA-2M-300, KAM-500, KA-300, and Craelius W3. They are particularly suitable as follows: (1) KA-2M-300 for drilling down to 300 m dia 55 to 115 mm. Capable of lifting 1½ tons at 0·5 to 0·65 m/sec; (2) KAM-500 for depths 500 to 750 m dia 65 to 190 mm. Capable of lifting 2 tons at 0·366–0·61–1·02 m/sec; (3) KA-300 is a rig mounted on wheel-base suitable for soft formations down to 100 m depth, and (4) Craelius W3 is most suitable for exploratory drilling for coal, since using 60- or 50-mm drill-pipe it will reach depths of 800 or 1200 m respectively. An automatic system of levers for the control and indicating of pressure on the bit at the bottom of the well is also fully described as well as progress recording mechanism.

Also included in the review are: (1) report on achievements of A. H. Kafarov, who proved that over a score of apparently exhausted wells could be made to produce effectively by practical use of scientific methods; (2) note on Soviet Petroleum Minister's article on effect of scientific exploitation like repressurizing, displacement with water, and directional drilling. M. S.

2584. Application of the "Es-Ka 2" coring apparatus for percussion drilling. S. Krimmer. *Nafta*, 1951, **7**, 126–8. (*From work of Polish Petrol. Inst.*)—Description of the improved coring apparatus "Es-Ka" previously described in *Nafta*, Dec. 1947, tests on which have been carried out since then. It consists of two parts, the coring apparatus itself fitting inside a "chisel" bit. Two sizes of these are respectively 10 and 7 inches long and 4 or 6 inches O.D.

Method of use is given in detail, and two drawings are included. M. S.

2585. Well cementation. R. P. Moscrip. *Proc. 3rd World Petrol. Congr.*, 1951, **2**, 144–61.—The results of an investigation into cementation practices using a centralizer-scratcher-reciprocating technique are described. The use of the technique has resulted in considerable economy by obtaining an increased percentage of successful primary cementations and the elimination of many expensive squeeze jobs. Standard precautionary squeezing prior to the completion has also been eliminated.

Successful cementation requires thorough advanced planning and competent supervision of the operations.

Caliper, radioactivity, and temp surveys, the equipment required, and the operations of cementation are described.

Charts showing mud conditions during stage cementation and the variations of casing string weight during cementation are included, together with ten references. C. A. F.

2586. Setting of thixotropic clay suspensions. W. Gründer, C. Ghisoiu, and D. Gligor. *Erdöl u. Kohle*, 1951, **4**, 760–5.—To measure the setting of drilling muds a viscometer was built with cylindrical body and outflow jet, the mud level during test being held constant. Ten overflow tubes at different levels in the side of the viscometer vessel were provided, and a continuous supply of mud was obtained from an overhead cyl. Both supply cyl and viscometer were thermostatically controlled. By plotting flow times for 3-litre outputs against time of standing between measurements, a series of curves is obtained for the ten pressures represented by the different overflow levels. It was found that for any given pressure except the lowest the rate of flow remains more or less constant over a range of standing times; this figure is taken as a measure of the flow characteristics of the mud at that particular pressure. Calibrating the instrument with ethylene glycol at different temps makes it possible to express this flow characteristic in terms of an equivalent visc in cp, and the curve finally obtained is that in which equivalent visc in cp is plotted against pressure. S. E. C.

2587. How to control circulation loss. W. C. Goins, Jr. *Oil Gas J.*, 9.6.52, **51** (5), 71.—A study of Gulf Coast conditions has led the author to believe that induced fracturing of weak formations is the greatest cause of lost circulation. Pressure gradients as low as 0·55 to 0·60 p.s.i/ft of depth are sufficient to fracture certain formations. Such pressures are produced by a mud column of 10·5 lb/gal density, and are greatly exceeded by surges resulting from rapid running into hole or spudding pipe while circulating—especially if annular clearance is reduced by balling. If induced fracturing is suspected, density, visc, and gel strength should be kept to the min safe value. Pipe movement rates should be reduced. In sticky formations oil emulsion muds help prevent balling. Among sealing materials sodium silicate mud and bentonite–diesel oil mixtures are particularly useful. J. C. M. T.

2588. Standards for casing centralizer tests. W. S. Althouse and E. H. Clark. *Proc. 3rd World Petrol. Congr.*, 1951, **2**, 58–73.—Standard tests are necessary for casing centralizers in order to obtain the proper spacing to ensure a satisfactory primary cementation job and to provide the operator with a uniform basis for comparing centralizers of different manufacturers.

Tests were carried out to determine the weight required to start and to slide each centralizer into the surface casing, the capacity of the centralizers to reach bottom hole without damage, and the spacing of centralizers for any given hole condition.

The test techniques are described in detail. C. A. F.

2589. Jet nozzled rock bits. L. L. Payne and R. H. Nolley. *Oil Gas J.*, 2.6.52, **51** (4), 76.—The jet bit has nozzles directed on to the bottom of the hole ahead of the cutters, and relies on turbulence to clear cutter teeth. Min jet velocities of 200 f.p.s. are often used together with a circulation rate of 180 f.p.m. around the annulus. Method and tables are given for finding the necessary pump capacity, pressures, and h.p. to achieve the velocities required. J. C. M. T.

Production

2590. Applications of a new measuring cable. K. Brüning. *Erdöl u. Kohle*, 1951, **4**, 693–4.—The use of the Schmid and Lechler cable in the electrical determination of salt water levels and for the Maihak pressure recorder is described. S. E. C.

2591. Cable for borehole instruments. C. Schmid and S. Lechler. *Erdöl u. Kohle*, 1951, **4**, 692–3.—The surface recording of electrical measurements made by an instrument suspended in a borehole demands a cable which has high resistance to wear, small dia, smooth surface, little stretch, flexibility, and insulation with excellent electrical and mechanical properties. The mechanical and electrical connexions between cable and instrument must also be first class. The design of such a connector and cable is discussed. S. E. C.

2592. Petroleum-engineering study of K.M.A. reservoir, southwestern part of K.M.A. oilfield, Wichita and Archer counties, Texas. R. P. Dobyns, M. L. Ayers, and R. E. Lewis. *Rep. Invest. U.S. Bur. Min.*, 4892, June 1952.—The K.M.A. field was dis-

covered in March 1931, but owing to low initial production, development was slow, until in 1937 a wildcat southwest of the discovery well gave high production of a 43° API gravity crude. This started rapid development of the southwest portion of the reservoir, and 700 wells were drilled over an area of 12,500 acres which were highly productive. A serious decline in reservoir pressure during the development caused the formation of a co-operative pressure-maintenance association at the end of 1939, and gasoline plants in the district returned dry gas to the injection wells for re-pressuring. By 1.8.49 approx 27% of the cumulative volume of gas produced had been returned to the reservoir. The resultant increased recovery of oil is shown to have been 12·2% greater than the calculated theoretical recovery without gas-injection. As the estimated initial volume in the reservoir was 168,000,000 brl, the recovery to 1.8.49 was 27·4% of the oil in place. Ultimate recovery by gas-injection is estimated to be 53,000,000 brl, or 31·5% of the initial volume in reservoir. Calculations for the theoretical performance of one 20-acre, five-spot-pattern water flood for the reservoir indicated that approx as much additional oil could be recovered by water flooding as had been recovered by 1.8.49. The engineering and operating aspects of water injection are discussed. W. H. C.

2593. Water flooding in Nowata County, Okla, oilfields. J. P. Powell and J. L. Eakin. *Rep. Invest. U.S. Bur. Min.*, 4896, June 1952.—Oil development in the county began in 1884, and its early history is described. Subsequent drilling and development work are discussed, and production figures from 1905 to 1951 are recorded. After the first flush of oil production passed, vacuum was applied to wells throughout the county. Gas-injection was first used in 1917 at a well 4 miles northeast of Nowata town, but air and gas injection did not become common practice until about eight years later. Water-flooding was introduced in 1935, and within six years had raised the production rate by about 150%. It is estimated that to 1952: (1) 100,000,000 brl of oil would have been recovered had no secondary-recovery methods been used; (2) gas-injection resulted in an increased recovery of 14,000,000 brl. Water-flooding has resulted in the recovery of an additional 34,800,000 brl, bringing estimated total oil recovery to nearly 150,000,000 brl. Four of the nine projects covered by the report are described in detail as to production history, methods of operating, types of equipment, methods of water treatment, and the results obtained are given. In the summary of water-flood performance for each project, figures are given of the number of brl of water injected for each brl of oil produced. W. H. C.

2594. A survey of oil production in Oklahoma by water flooding. Pt 1. Nowata, Rogers, and Craig County. Pt 2. Counties other than Nowata, Rogers, and Craig. J. P. Powell and K. H. Johnston. *Rep. Invest. U.S. Bur. Min.*, 4831, Feb. 1952, 4832, Nov. 1951.—These reports on the water-flooding activities in Oklahoma covering the period from July 1942 to the end of 1949, supplement the data recorded in *Rep. Invest.* 3728 (Abs. No. 1373—1944). They give details of each project, describe the operations, and give data covering the production history of the property, before and during water-flooding, production practices, sources and treatment of water used, and the results obtained in the counties indicated. By the end of 1949, twenty-five of the forty-nine oil producing counties had been subjected to water-flooding. Approx 33,000,000 brl of oil, or 1806 brl/acre, had been recovered by the end of 1949, from 18,221 productive acres included in the 162 active and abandoned projects in Oklahoma by injection of approx 442,000,000 brl water. W. H. C.

2595. Odin water flood project, Marion County, Illinois. L. Krause. *Oil Gas J.*, 9.6.52, **51** (5), 94.—The production of Odin field, discovered in May 1945, had by 1949 fallen to 92 b.d. After water flooding had been put into operation the production was raised to over 1200 b.d. in 1951. Production is from the Cypress sand at 1750 ft, which has an average permeability of 80 mD, connate water saturation of 33%, and relative permeability at residual saturation of 13·5%. Production is from twenty-five wells on a 10-acre spacing. Water for the ten peripheral input wells is supplied by the 1600-ft-deep Tar Springs formation, using a closed pumping, filtering, and storage system. Complex metaphosphates are added to hold mineral material in solution. J. C. M. T.

2596. Indiana's largest active water flood. Anon. *Oil Gas J.*, 9.6.52, **51** (5), 80.—The Berry Skelton field, east of the river Wabash opposite Rochester, Ill., was first produced in June 1948 at 1905 ft in the Waltersburg sand. It consists of a long narrow stratigraphic trap with gently dipping beds. The water flood programme was begun in 1950, using water from shallow river gravel after filtration and treatment. Ten months later production had risen from 500 to 2000 b.d., and it is anticipated that it can be held at this level for about three years. About 8000 b.d. of water are at present injected into nine wells at 1200 p.s.i. J. C. M. T.

2597. Visual examination of fluid saturation in porous media. D. A. Wilson, J. C. Calhoun, Jr., and A. Chatenever. *Oil Gas J.*, 26.5.52, **51** (3), 175.—The method involves preparing artificial cores of water soluble material, then saturating the core with two liquids, one soluble, the other solidifiable and insoluble in water. Leaching the cores with water removes all but the solid flow structure of the second liquid.

In the experiments described sodium chloride was used to represent sand grains, being consolidated under pressure to form a " core." Porosities around 25% were obtained. In test runs melted paraffin wax and glycerine, at 137° F, were flowed through the " cores," and paraffin saturation determined for equilibrium flow conditions. The salt and glycerine, after chilling, were removed with water.

Measured permeabilities and saturation values for tests on eleven such " cores " are given, together with photographs showing the paraffin wax networks, and the porosity patterns of salt cores. J. C. M. T.

2598. Volumetrically weighting reservoir data. K. A. Anderson. *Oil Gas J.*, 26.5.52, **51** (3), 202.—A rapid method for obtaining volumes for use in obtaining weighted averages of reservoir pressure, permeability, etc., based on polygons surrounding each well for which data are available, in conjunction with an isopachyte map, is described. The polygons are obtained by joining the centroids of the triangles formed by drawing lines between adjacent wells, to the mid points of these lines.

The method assumes that data measured at a well bore are representative of the prism surrounding the well, and that variation in values from one well to another are approx linear in form. J. C. M. T.

2599. Surface tension of Polish crude oils. J. J. Glogoczowski and K. Czaplicka. *Nafta*, 1951, **7**, 160–3. (*From work of Polish Petroleum Institute.*)—The wetting power of crude and water influences their movement through rocks. Authors describe some methods and instruments for determination of surface tension. Tables and graphs giving critical interfacial tension between various crudes and water containing various salts are included.

Further work is anticipated. M. S.

2600. Bringing-in crude oil and natural gas wells. Z. Wilk. *Nafta*, 1951, **7**, 170–6.—Discusses the relations between teaching and practice of petroleum industry. In bringing-in wells theory accounts only for some 20% of the steps taken. Methodical approach pays dividends in elucidating coring and logging methods.

If the pressure of the formation is high slight variation in dia of the hole may cause great differences in flow. For this reason " rat holes " are employed.

Details of appropriate samplers are given, together with instructions for use.

M. S.

Oilfield Development

2601. Exploratory drilling in 1951. F. H. Lahee. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 977.—This is the 7th annual report on statistics of exploratory drilling in the U.S., and the fourth report on Mexico and Canada.

The total exploratory footage drilled in the U.S. in 1951 was 49,343,694 ft in the 11,756 holes; of these 6189 were new-field wildcats, 684 being successful; 3062 were new-pool tests (including new-pool wildcats, deeper-pool tests, and shallower-pool tests), 851 were successful, and finally, 2503 were outposts—680 were successful. These figures compare with 40,175,173 ft drilled in 10,306 exploratory holes, with an average depth of 3898 ft in 1950.

In western Canada 1951 saw the completion of 483 exploratory holes, 134 being producers, and 349 dry holes. A total of 1,994,027 ft was drilled. Ten of the fifty-six exploratory holes drilled in eastern Canada (where a total of 103,967 ft was drilled) were successful.

This year also saw a total of 528,393 ft drilled in Mexico, making a total of 130 exploratory holes, forty-one being successful. E. N. T.

2602. Developments in Pennsylvanian in 1951. C. R. Fettke. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1047.—Major drilling activity in Pennsylvania during 1951 was confined to the Oriskany sand gas territory in the north-central part of the state. The total number of shallow wells drilled was 3% less than in 1950, with the discovery of one small shallow sand oil pool in southwestern Pennsylvania, and one in north central Pennsylvania, both Upper Devonian.

The average oil production for the entire state for 1951 was 31,095 brl, as compared with 32,488 brl in 1950. There was, however, an increase over the 1950 total of deep wells drilled—fifty-seven gas wells and twenty-seven dry holes as against 1950s total of thirty-four in all.

An extension has been made to the Leidy gas field in Clinton County, the average production of which for 1951 was 150 million cu. ft. of gas/day. Five other prominent structures were completed, one of which was successful and will probably lead to another Oriskany sand gas field. E. N. T.

2603. Developments in New York in 1951. E. R. McAuslan. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1043.—The Oriskany sand of Lower Devonian age has for the past twenty-three years been the most prolific gas sand of the State, but is declining in importance. In this area five wells were completed, and gas production amounted to 1,115,721 M.c.f.; 897 development oil wells were drilled during the year, and pipeline runs of oil amounted to 4,247,365 brl. Twelve shallow tests were drilled during 1951, compared with five in 1950, none of which were successful. There was no geophysical activity during the year. E. N. T.

2604. Developments in Atlantic Coastal States between New Jersey and South Carolina in 1951. H. G. Richards. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1238.—On the Coastal Plain only three dry wells were drilled, in North Carolina; in Maryland thirteen wells were drilled, nine of which produced gas; and activity continued in Virginia, with some oil and gas produced. E. N. T.

2605. Oil and gas developments in West Virginia in 1951. R. C. Tucker. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1063.—There was a decrease of forty-eight in the total number of wells drilled in West Virginia in 1951 compared with 1950, *i.e.*, 696 against 744. There was also a decrease shown of 104 in the permits to drill or deepen on the 1950 figure of 848.

However, 463 gas wells were completed with seventy-one oil, fifteen oil and gas; storage, brine, water injection, and pressure thirty; and 117 dry holes. The average depth of wells was 2895 ft, showing an increase of 227 ft over 1950. The total footage drilled was 2,014,576 ft, whilst the initial daily open flow of the gas wells was 355,853 M.c.f., a decrease of 112,541 M.c.f. under 1950. Preliminary estimates of production of 1951 were gas, 194,630,000 M.c.f., a decrease of 2,580,000 M.c.f. under 1950; and oil 2,757,000 brl, showing a decrease of 31,000 brl under 1950. The estimated number of producing wells at the end of 1951 was 14,000 gas wells and another 14,000 oil wells. E. N. T.

2606. Developments in Southeastern States in 1951. L. J. Finfrock. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1228.—In Alabama, Florida, Georgia, and Mississippi there were 1169 crew weeks worked, a decline of 185½ from the 1950 total. The total number of wildcats was 175 against 169 in 1950, and development wells totalled 261 against 211, resulting in fifteen new fields, nine new pools, and two salt domes. Production of oil and distillate was 41,561,000 brl, and gas production was 159,419 M.c.f. in Mississippi alone, with small amounts from Alabama and Florida.

Twenty-eight wildcats were drilled in Alabama, with no new discoveries and one

field extension; eighteen development wells were producers, and eleven were dry holes. Florida had only three wildcat wells, no development wells being completed. There were no wildcats drilled in Georgia, but 175 were drilled in Mississippi, where fifteen new fields, nine new pools, and two salt domes were found; development wells totalled 202, with seventy-four dry holes.

Alabama's oil production totalled 1,031,000 brl, Florida produced 597,000 brl, and Mississippi 39,933,000 brl, with 159,419 M.c.f. of gas. Crew weeks in Alabama reached 3$\frac{1}{2}$1, an increase of 125 over 1950; in Florida only forty-six crew weeks were worked, a decrease of eighteen; and in Mississippi 812 crew weeks were worked, a decrease of 290$\frac{1}{2}$ weeks. E. N. T.

2607. Developments in North Texas in 1951. J. R. Kiene and B. E. McMahon. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1157.—The major leasing activity in North Texas during 1951 was concentrated in Collin County and southern Grayson County. Production increased to 59,816,500 brl of oil, and gas production to 75,356 M.c.f. for the whole area. During the year, 3094 tests were drilled, 831 being exploratory.

Amongst the more important discoveries were the stratigraphic accumulation in Pennsylvanian sandstones, Grayson County field; structural accumulation in three Strawn sandstones, Grayson County field and Baylor County (this last also included stratigraphic accumulation); Caddo limestone production in southern Wise County, and lower Pennsylvanian production in Foard County.

The seismograph was the leading exploratory tool in the exploration of North Texas; about 28% of this work was concentrated in Grayson County. E. N. T.

2608. Developments in East Texas in 1951. J. L. Read, Jr. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1188.—East Texan exploratory drilling rose 43% over 1950: of the 242 exploratory wells, sixteen were oil wells and fourteen gas-condensate wells. A new gas-condensate field in Rains County has the potentialities of a new sulphur reserve; and the more important new fields showed a trend towards increasing gas-condensate rather than oil reserves.

Drilling operations in proved areas declined. New producing zones were located at Ham Gossett, Walter Fair, Buffalo, Tennessee Colony, and Scottsville fields. The East Texas field was again the most active, 73% of the total accumulated production in the district having come from this field.

Geophysical exploration increased 15·6%, and leasing activity increased by almost 200%. E. N. T.

2609. Developments in Texas Panhandle in 1951. J. M. De Long. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1120.—Geophysical activity in the Panhandle district of Texas showed an increase over 1950, whilst there was a decrease in leasing activity. During 1951, 727 development and forty-nine exploratory wells were drilled; no new fields were discovered, but seven exploratory tests were completed as field extensions and three as new-pool discoveries.

There was an increase on the gas production over the previous year, but oil production declined to 31 million brl. E. N. T.

2610. Developments in West-Central Texas in 1951. K. Waddell. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1169.—Oil production was increased from 25,752,000 brl in 1950 to 29,562,214 brl in 1951, and 2637 test wells were drilled, of which 1255 were successfully completed, 167 of these being exploratory discoveries. Sixty-seven new fields were discovered, compared with fifty-eight in 1950.

Most of the discoveries were in Stonewall, Haskell, and Throckmorton counties, the Katz Strawn sand field in northeast Stonewall being the leading discovery in the area: 40% of the discoveries were in Strawn sediments, and sixteen of the twenty-four counties recorded new-field discoveries. Geophysical activity continued to decline, crew weeks decreasing 55%, and leasing activity was greatest in Taylor, Coleman, and Callahan counties, where there are Strawn sand trends. E. N. T.

2611. Developments in West Texas and southeast New Mexico in 1951. A. H. Hedden, Jr., *et al.* *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1128.—The year 1951 showed an increase in exploratory and development activity in the West Texas–Southeast New Mexico districts.

The seismograph was used more extensively than ever before in the increased geophysical and exploratory activity. Spraberry wildcatting and development drilling dominated the Permian basin activities of 1951. The other outstanding developments were pre-Permian discoveries in the Midland Basin; continued successful wildcatting in the Northwestern Shelf area of New Mexico and the Delaware Basin, and an intensive search for Pennsylvanian reef oil in the southern part of the Eastern shelf.

Following on this highly successful year, it appears that shortage of tubular goods will be the only curb on the prospects for 1952. E. N. T.

2612. Developments in South Texas in 1951. J. K. Rogers, W. H. Spice, Jr., and L. R. Vesely. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1177.—The increase in drilling activity noted in 1950 was continued, 3,112 wells being drilled. Exploratory tests increased by 10·7%, while development tests remained about the same as in 1950, both classes being tabulated by geological trends. New-field discoveries were not outstanding, the best discovery rate being in Eocene trends, but important reserves have been added by over 200 extensions and new-sand discoveries, mainly in the down-dip Frio-Vicksburg and in the Gohlke field of the Wilcox trend.

During the year, 163,200,000 brl of crude oil and 22,051,657 brl of hydrocarbon liquids were produced, an increase of 25 and 15% respectively over 1950; free gas well production was 977 billion (U.S.) cu. ft., 35% more than in 1950. E. N. T.

2613. Development in Upper Gulf Coast District of Texas in 1951. W. W. McMahan, Jr. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1201.—In 1951, 1552 wells were drilled in the twenty-nine counties of the district, and thirty-seven new fields were discovered, including fifteen oilfields, eighteen gas distillate fields, and four gas fields, all of minor importance. Old fields added more reserves than did new discoveries: 1314 wells were drilled on known structures, 988 of them being successful.

Oil and condensate production totalled 180,401,000 brl, 20% more than in 1950. Geophysical activity totalled 2190 crew weeks, 90% in reflection seismograph time, the most successful exploration method when used in conjunction with subsurface geology. E. N. T.

2614. Developments in Louisiana Gulf Coast in 1951. G. G. Iles. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1211.—Drilling activity in this region dropped over 10%, 1007 wells being completed against 1121 in 1950, 334 of them exploratory and 673 field development wells. About 36·5% of the exploratory wells and 75·18 of the development wells were successful. Of the 142 new-field wildcat tests, twenty-four new fields were discovered, 3% more than in 1950, twelve being oilfields, ten gas condensate fields, and two gas fields. There were 192 exploratory tests drilled on producing structures, against 135 in 1950; ninety were new-pool wildcats, 43% being successful; sixteen shallow pool tests, 87·5 successful; forty-five deeper pool tests, 84·4% successful, and forty-one outposts, 17% being successful.

Seismic activity increased, with 924 crew months worked, compared with 623 in 1950: there were 166 crew months of gravity meter survey worked, compared with ninety in 1950. Production reached a record of 190,954,994 brl of oil and condensate, against 167,427,924 brl in 1950. About 836,312,570 M.c.f. of gas was produced, compared with 5486,08,826 M.c.f. in the previous year. E. N. T.

2615. Developments in Arkansas and North Louisiana in 1951. S. A. Womack, Jr., and H. B. Hundley. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1220.—There was a 5% decrease in drilling activity in the district, with 340 exploratory wells and 1328 field wells drilled. Production was 82,554,990 brl, compared with 82,829,610 brl in 1950, and sixteen new oilfields and four new gas-distillate fields were discovered, as well as four extensions and seventeen new producing zones added to proved fields. Most of the new discoveries were in the Eocene trend.

There was little change in geophysical activity; thirteen of the new discoveries were made by subsurface geology, but seismic geophysics attained the highest percentage of success. E. N. T.

2616. Developments in Arizona, western New Mexico and northern New Mexico in 1951. P. H. Umbach and F. C. Barnes. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1147.—The area of this report includes northern and western New Mexico and the state

of Arizona. A total of 276 wells were drilled in the former districts, fifty-three being wildcats, of which 39% were productive, showing an increase of 167 over the 1950 total.

Arizona was limited to five wells, all dry-hole wildcats, compared with seven (also dry holes) drilled during 1950.

There are more oilfields due to new oil discoveries; 391,930 brl being produced during the year, as against 333,697 brl in 1950. At the end of the year there were seven gas pools and nine oilfields, compared with the nine gas pools and seven oilfields of the previous year, this being due to the merger of several gas pools into the Blanco trend. E. N. T.

2617. Oil and gas developments in Kentucky in 1951. E. B. Wood and M. A. McCarville. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1067.—Several significant discoveries were made throughout Kentucky in 1951. The total, including fields, pools, new pays in old fields, and outposts, rose from seventy in 1950 to seventy-nine in 1951. A record of more than 11 million brl of oil were produced due to the considerable increase in drilling activity.

Western Kentucky accounted for most of the new discoveries, and 83·8% of the total oil produced, whilst south-central Kentucky's increase was due to many more completions reported in Allen and Warren counties, and to a new-field discovery in Monroe County.

There were no new discoveries in the eastern section of Kentucky during 1951. E. N. T.

2618. Oil and gas developments in Tennessee in 1951. H. C. Milhous. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1075.—Oil was produced in the five adjoining counties of north-east-central Tennessee out of the fifteen counties that had seen some drilling activities in 1951. On the whole, there were slight improvements in the number of tests drilled, the successful wells, the total exploratory footage drilled, and the production of both oil and gas. E. N. T.

2619. Developments in Wyoming and Idaho in 1951. M. D. Hubley. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1023.—Exploratory drilling in Wyoming during 1951 represented an increase in footage drilled over the previous record exploratory year—1950, thus making a total footage of 1,038,762 ft drilled in 1951.

The majority of the forty-two discoveries during this year involved stratigraphic trap or fault trap conditions controlling the accumulations. Faulting is considered an important accumulation factor in seven of the eleven new fields discovered in 1951. Significant discoveries included Whistle Creek, West Sussex, North Fork, and East Salt Creek as new fields, and new pools at South Cole Creek, Sussex, Beaver Creek, and South Elk Basin. The Slick Creek field was considerably enlarged. A considerable trend towards the utilization of Government land is apparent in Wyoming, wherein twenty unit agreements were approved in 1951, compared with eleven in 1950.

Wyoming oil production in 1951 set a new record of about 69 million brl, 14% above the 1950 production. Gas production totalled 83 million M.c.f., 5% above 1950. Sulphur production from the processing of natural gas totalled about 111,900 long tons in 1951.

Idaho, however, continued as a state having no oil production. E. N. T.

2620. Developments in Oklahoma in 1951. M. D. Maravich. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1107.—In contrast to previous years, wildcat drilling failed to uncover any Oklahoma fields of major importance during 1951; exploratory drilling showed a slight decrease, even though the total number of wells drilled was greater than in 1950. However, there was a considerable increase of overall reserves, due to the discovery of new zones in old fields, and many additional secondary-recovery projects. E. N. T.

2621. Developments in Michigan in 1951. W. A. Sanger. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1091.—Although the total number of wells completed during 1951 showed a decline as against 1950, on the whole, exploratory drilling in Michigan during 1951 showed a slight increase. Development drilling declined very sharply, and the production of oil and gas continued to drop. Geological testing continued at the high level set in 1950. E. N. T.

2622. Developments in Illinois and Indiana in 1951. A. H. Bell and R. C. Cooper. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1079.—Compared with the previous year, 1951 showed a decrease of 16·5%, only 3702 oil and gas wells being drilled in Illinois and Indiana as against 4424 in 1950. Wildcat drilling increased from 1334 completions in 1950 to 1483 completions in 1951. Sixty-nine new pools, seventy-six extensions, and fifty-two new producing zones were discovered in the two states in 1951.

The majority of the discoveries were in Mississippian formations. Six new pools were discovered in Pennsylvanian sandstones, seven in Devonian or Silurian limestones, and one in Ordovician limestones. E. N. T.

2623. Developments in Ohio in 1951. R. L. Alkire. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1058.—No new oil pools of note were discovered in this area during 1951, and the sharp decline in gas well drilling which began in 1950 continued. Two discoveries at the end of the year hinted at a more successful gas development during 1952.

Total wells drilled amounted to 1061, of which 626 were producers and 435 were dry. E. N. T.

2624. Developments in Montana, North Dakota, and South Dakota in 1951. H. D. Hadley and G. W. Smith. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1014.—After thirty-three years of intermittent exploration, North Dakota and the Williston Basin part of Montana have, for the first time, contributed production statistics.

All indications point towards a substantial increase in drilling during 1952 as shown by the Amerada Petroleum Corp's C. Iverson well No. 1, which has precipitated an expanded leasing and exploration programme in Montana, North Dakota, and South Dakota.

Palæozoic rocks compose most of the newly discovered reservoirs, with production indicated from rock of Ordovician, Silurian (?), Devonian, and Mississippian age. E. N. T.

2625. Developments in north Mid-Continent in 1951. D. W. Payne. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1098.—This report covers the activity in Kansas Missouri, Iowa, and Nebraska east of the 100th meridian. Activity in all of these states except Kansas was relatively subordinate.

More than 4500 wells were drilled, out of which total exploration accounted for 1366 wells, discovering 146 oil pools, seven gas pools, and 111 classified as either extensions or new producing zones in old pools. A new record production of 1,060,928 brl of oil was reached from new-well completions in 1951 ; Kansas producing 118,084,607 brl of oil and casinghead gasoline, which was a new production record, and as a result of these new discoveries an active leasing campaign is now being carried on. E. N. T.

2626. Developments in Colorado, Nebraska, and Utah in 1951. J. Marshall and A. Saterdal. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1033.—East Colorado accounted for the main increase in development drilling in this three-state area over the previous year. Exploratory drilling, with a total of 298 tests, was nearly double that of 1950, but only forty-six were successful, showing a decrease in the success ratio. Most of the new discoveries were from Cretaceous sands, with Eocene zones largely in Utah. The Denver–Cheyenne Basin accounted for several additional zones, whilst the Eocene Wasatch and Cretaceous Mesaverde produced for the first time in Utah and western Colorado.

A marked increase in seismic work was shown, particularly in East Colorado, it was also the basis for locating the majority of the exploratory tests and discoveries, but surface data were important in western Colorado and Utah, although in the Denver–Cheyenne Basin, and in Utah, the importance of favourable sand development has become increasingly evident.

Leasing continued active, with important plays in central Nebraska, southeast Colorado, the Piceance Creek Basin of Colorado, and the Basin-and-Range Province of Utah. E. N. T.

2627. Developments in West Coast area in 1951. G. B. Moody. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 996.—In 1951 the approx production of crude oil in this area was 354·6 million brl, 29·5 million brl of natural gas liquids, and 511·2 billion (U.S.) cu. ft. of gas, with sixty-five exploratory wells active by the end of this year.

Washington produced one unsuccessful new-field wildcat, Oregon three unsuccessful new-field wildcats, with a total drilling of 13,216 ft, and Nevada five unsuccessful new-field wildcats—total drilling 11,913 ft.

In California, the total exploratory footage in 577 exploratory wells finished in 1951 was 2,362,302 ft, compared with 489 wells in 1950. Out of these nine new fields and twenty-one new pools none has given evidence of being a major discovery.

Successful outposts and step-out development wells extended the productive limits and increased the reserves of numerous fields in 1951. E. N. T.

2628. Developments in Eastern Canada in 1951. W. A. Roliff. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1252.—A total of fifty-six wells was drilled in Eastern Canada in 1951 as compared with sixty-two wells in 1950, but exploration in south-western Ontario was more successful, six new gas pools, two deeper gas pools, and two shallow oil pools having been discovered. Gravity surveys were continued in that area and in Newfoundland, and development drilling over Eastern Canada continued at roughly the same rate as in 1950, 264 development wells being completed, 262 in Ontario and two in New Brunswick. Oil production totalled 216,918 brl, and gas production 8,865,096 M.c.f. E. N. T.

2629. Canadian oil before Leduc. Anon. *Petroleum*, Aug. 1952, **15** (8), 207–9.—A review of the growth of the Canadian oil industry from 1859 to 1947 summarized from the Shell Oil Co. Canada Ltd. booklet on "Canadian Oil: A Century of Progress." R. E. P.

2630. Developments in Western Canada in 1951. A. J. Goodman. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1260.—In 1951, 1270 wells were drilled in Western Canada, 485 being exploratory tests, and 218 rigs were operating. Of 153 geophysical parties, 142 were operating seismic surveys. Alberta was the main centre of interest, but discoveries in Manitoba and western Saskatchewan have heightened interest in the Williston basin area, and there has been some renewed interest in the Rocky Mountain foot-hills.

Oil reserves in Western Canada have been estimated at about 1300 million brl, and gas reserves at about 8 trillion (U.S.) cu. ft. The Alberta Government showed great interest in the possibilities of the Athabaska tar sands as an oil source, and plans for a new pipeline outlet to the West Coast are going ahead. E. N. T.

2631. Oil industry in Alberta. R. S. M. Blair. *Petroleum*, Aug. 1952, **15** (8), 210–14.—The present position of the oil industry in Alberta and likely future developments are reviewed. Both oil and gas fields of Western Canada are described. Details are included of production and exploration, including details of crude availability and inspection data; oil development government controls; refining and selling; and transport. R. E. P.

2632. Athabaska tar sands. Anon. *Petroleum*, Aug. 1952, **15** (8), 215–16.—A brief description of the bituminous tar sands outcropping along the banks of the Athabaska River in Northern Alberta which constitute a source of potential fuel peculiar to Canada. The oil sands, which occur close to the surface over a considerable area, are composed largely of unconsolidated silica sand that in places is saturated with a heavy viscous oil. It is known that there are single sq. miles within the formation that contain as much as 200 million brl of recoverable oil. The crude in such a sq. mile could contain as much as 1½ million tons of sulphur, a component that has to be reduced in quantity, and of which over one-half could be recovered during refining. Special methods have been developed for oil evaluation and processing. R. E. P.

2633. Developments in Alaska in 1951. G. Gryc. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1242.—Since the U.S. Navy began its current exploration programme in 1944, interest in the petroleum possibilities of Alaska has been increasing. Alaska

produced no petroleum for commercial use in 1951, but a small amount of gas was produced from the Barrow gas field. Four U.S. geologic parties and one seismic party were in the field in Northern Alaska, and in addition 47,864 ft were drilled in nineteen core holes and test wells. Topagoruk No. 1 was drilled to 10,503 ft to Devonian beds, all other test wells being drilled in Cretaceous rock, except Avak No. 1, which drilled into pre-Cretaceous rock. The presence of a sizable oilfield has been proved by further drilling in the Umiat field, estimates of potentialities ranging from 30 million to 100 million brl. Three wells indicated gas in the Umiat and Gubik anticlines. E. N. T.

2634. Developments in Mexico in 1951. E. J. Guzman and U. F. Mina. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (6), 1274.—In 1951, 268 wells were drilled in Mexico, 129 of them exploratory tests, of which forty-one were producers. Total footage drilled was 1,095,875 ft. Discoveries included six new oil or gas fields, twenty-four new pools, and twelve extensions, methods including reflection-seismograph work, surface and subsurface geology, and gravity-meter and electrical-resistivity surveys. Surface geology and geophysical exploration increased from 262 to 275 crew months.

Production of crude oil and distillates totalled 77,308,250 brl, 4,882,096 brl more than in 1950, and gas production was 86,214,231,071 cu. ft. E. N. T.

2635. Petroleum developments in South America and Caribbean area in 1951. J. F. Mason. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (7), 1330.—The most significant increases for 1951 were in Brazil, Chile, Colombia, and Venezuela, the last-named country maintaining its position as the major oil exporting country of the Western Hemisphere. Bolivia was the only country to show any loss.

The approx daily average crude oil production in South America for 1951 was 1,975,100 brl, an increase of 13% over the 1950 average, whilst the Caribbean showed a decrease of 51% over last year.

A total of 2030 wells were drilled in South America in 1951; of this total 1704 were oil-wells, twenty-nine gas, and 297 dry wells.

The notable increase in production was achieved over a period in which drilling activities were stepped up.

The Motembo and Jarahueca fields of central Cuba in the Caribbean area are the only source of oil in this area. Between them they produce 49 b.d. of oil, making a total over the year of 17,900 brl. Geological survey work is being carried out in Barbados, British Honduras, and Cuba. Exploration licences are still held by the Bahamas Oil Co. and Bahamas Exploration Co., but no activity has been reported in the Bahamas area during year. E. N. T.

2636. Review of Venezuelan oil activities in 1951. Anon. *Petrol. Times*, 25.7.52, **56**, 621.—The continued expansion of the Venezuelan oil industry is reviewed, and the significance of the recently created Venezuelan Ministry of Mines and Hydrocarbons on the future of oil exploration and exploitation is discussed. Petroleum exports from Venezuela in 1951 confirm Venezuela as by far the largest oil-exporting country in the world. J. H. P.

2637. Petroleum developments in Europe in 1951. F. E. von Estorff. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (7), 1359.—Production of crude oil during 1951 remained fairly constant in the Netherlands, Great Britain, and Italy, and active exploration was carried on in Western Austria, Denmark, Portugal, and Spain. The Lacq field in southern France, and a new field in western Germany, together with the discovery of new producing formations and the development of old fields, have led to a rise in the relatively small production of western Europe: crude oil output, including condensate, having increased to more than 17,000,000 brl in 1951, a rise of 3,000,000 brl over the previous year.

The omission of Eastern Europe from this report is due to lack of reliable information. E. N. T.

2638. New aspects of the oil country on both sides of the German-Dutch border. Anon. *Erdöl u. Kohle*, 1951, **4**, 549.—The Frenswegen I well proved gas-bearing at 1925 m in the Plattendolomit with max closed-in pressure of 200 atm and capacity 50,000 to

80,000 cu. m/day. In view of the productive Zechstein of Bentheim and Coevorden, this discovery increases interest in the Nordhorn area. Tubbergen 4 on the Dutch side and Itterbeck–Halle I on the German side of the Nordhorn anticline have both found gas, and Frenswegen I now suggests that there is gas and perhaps even oil in the area between Bentheim and Coevorden. It is noteworthy that while the Bentheim gas is dry methane, that from Frenswegen contains an appreciable amount of higher hydrocarbons. S. E. C.

2639. Bavarian State reservations and prospecting permits. T. Ostern. *Erdöl u. Kohle*, 1951, **4**, 533–8.—The Bavarian mining law, in so far as it applies to mineral concessions and prospecting permits, is discussed, and details are given of the present distribution of permits and their holders in Upper and Lower Bavaria, Swabia, and Upper Pfalz. S. E. C.

2640. German drilling activity in 1951. H. Lögters. *Erdöl u. Kohle*, 1952, **5**, 273–83.—399 boreholes of combined depth 404,487 m were drilled in 1951. Twenty-five out of 125 exploration wells, and 235 out of 274 exploitation wells were productive, the total production for the year being 1,367,000 tons. Two new gas fields, Itterbeck and Frenswegen, were discovered in Emsland, and two new oilfields, Hemmelte, in the Weser–Ems region, and Hohne, in the Hanover–Celle district, were also discovered. In South Germany the greater part of the work has been done in the Rhine graben, where interest was further stimulated by a gas blow-out at Wolfskehlen, but exploration is also proceeding in the Molasse of Baden, Würtemberg, and Bavaria, and is encouraged by shows in Saulgau I. Proven reserves for the whole of Germany stand at 27·9 million tons, with additional probable reserves of 12 million tons.

The results of exploratory drilling are discussed in some detail for the following areas: North of the Elbe, between the Elbe and the Weser, between the Weser and the Ems, west of the Ems, Münster, Rhine graben, and Alpine foreland. S. E. C.

2641. Realization of the production and drilling plans of the Polish petroleum industry during the first half-year of 1951. S. Laskowski. *Nafta*, 1951, **7**, 184–5.—Achievement for first six months 1951 is given in two tables as % of planned effort for 1951 and as % of production for corresponding period of 1950.

Greatest progress has been registered in geological drilling, which rose more than sevenfold but is still below planned goal. Such shortcomings are due to lack of tools. M. S.

2642. Petroleum developments in Middle East and adjacent countries in 1951. R. C. Kerr and J. O. Nigra. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (7), 1427.—The 1951 petroleum output from the Persian Gulf countries reached a record level in spite of the seizure of the Anglo-Iranian Oil Co's properties by the Persian Government in September. The production averaged 1,906,100 b.d., exceeding the 1950 production by about 60,000,000 b.d. There was a slight increase over the 1950 yield from the India, Pakistan, Burma group of fields, resulting in an estimated production of 4,120,000 brl, an increase of 300,000 brl over the previous year.

Three new fields were discovered during the year—Garzan in Turkey, and 'Uthmaniyah and Safaniya in Saudi Arabia. Ain Dar in Saudi Arabia and Zubair in Iraq were provided with outlets and placed on production.

Geological and geophysical work was vigorously carried on in the Iraq Petroleum Co's group of concessions, the Kuwait neutral zone, Turkey, and Saudi Arabia, with a slow revival in India and Pakistan. Activity in Persia, however, was forced to a complete stop, whilst in Burma work is at present at a standstill. E. N. T.

2643. Petroleum developments in Africa in 1951. H. D. Hedberg. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (7), 1395.—The 1951 African petroleum production again reached a new record figure, the most extensive operations being carried out in Tunisia, Algeria, Nigeria, French Morocco, French Equatorial Africa, and Ethiopia.

Highlights in the year's exploration history are the recovery of 32° API oil in French Equatorial Africa, and the spudding-in of the first deep well in Nigeria and Madagascar. Additional productive palæozoic areas were discovered in Morocco, and extensive exploratory campaigns were carried out in Tunisia and Algeria.

Work in party months was approx as follows: surface geology 161+; seismograph 147; gravity 96+; telluric 35; structure drill 14; magnetometer 11+.

Egypt, the principal producer, showed a small decline, but increases in French Morocco and Algeria made up for this. The total footage drilled during the year was 547,241 ft, with a new all-time record in petroleum production of 16,915,259 brl. E. N. T.

2644. Petroleum developments in Far East in 1951. G. F. Barnwell. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (7), 1445.—On the whole, the crude oil output in the Far East has increased steadily since the war, although in comparison with that of the Middle East the Far East's contribution to the world's petroleum output is small.

The year 1951 saw a substantial increase of 37,168 b.d. over the 1950 daily production rate of 237,364 brl. Five discoveries were made this year, four being in South Sumatra and one in Netherlands New Guinea.

Indonesia and North Borneo were the main contributors to the Far Eastern petroleum output, followed by Netherlands New Guinea, on a minor scale, whilst Australia, New Zealand, Papua, and the Philippines made no contribution at all. Many of the countries in the Far East are large importers of crude oil and petroleum products, as a result of production not being sufficient to meet the requirements of the area.

Geological and geophysical activity has been carried out over the whole area but with little result. E. N. T.

Transport and Storage

2645. Effect of hydrodynamic forces on pipeline crossings of rivers. L. M. Odom and J. W. Higgs. *Oil Gas J.*, 28.7.52, **51** (12), 272.—Fundamental theory of turbulent flow is discussed, and basic derivations necessary for an understanding of the phenomena are given. Method by which pressure differentials resulting from turbulence may be calculated is illustrated, and effect of turbulence on submerged lines and characteristics of drag and the resulting loads are briefly considered. G. A. C.

2646. La Paz crude line operating. N. R. van Middlesworth. *World Petrol.*, 1952, **23** (6), 40–1.—Pipeline of 160 miles 30-inch pipe connects Palmarejo de Mara on west of Lake Maracaibo and the Paraguana peninsula. With completion of the only pump station, at Palmarejo, throughput will be increased to 235,000 b.d. or, with additional unit, to 290,000 b.d. max. Construction, anti-corrosion measures, and pumping equipment are described. E. B.

2647. Colombian products line in operation. Anon. *World Petrol.*, 1952, **23** (6), 50–1.—First of series of products lines has been completed between the refining centre at Puerto Salgar and Bogota, with capacity of 8000 b.d. Rail and road construction has lagged behind growth in population, and difficult mountain terrain favours transport by pipeline. Line is state-owned, and profits will be used to repay building costs. E. B.

2648. The Finnart–Grangemouth pipeline. Anon. *Fluid Handling*, June 1952, (29), 164–8; July 1952 (30), 197–204.—Two days' sailing time is saved by delivering Middle-East crude to the west coast of Scotland and pumping 57 miles to the Grangemouth refinery through a 12-inch buried pipeline.

The legal aspect of the construction of this line is outlined in Pt 1, and details are given of the welding, bending, and supporting of the line.

In Pt 2 the jetty and its equipment, capable of berthing the largest tankers at any state of the tide, is described. The dimensions and specifications are quoted for the tank farm and service lines, pumps, and manifolds.

Auxiliary services are steam for heating fuel oil and tracer lines, fire-fighting mains, and pumping equipment. D. H.

2649. Contributions of the gas turbine to big inch gas line pumping. Anon. *World Petrol.*, 1952, **23** (7), 36–7. (*Report on paper by T. J. Putz to Amer Soc. Mech. Engrs.*)—

Comparative studies have shown 26-inch O.D. pipeline could be economically developed to same delivery capacity with gas turbine driven centrifugal compressor as a 30-inch line with reciprocating equipment. A 1000-mile 26-inch line would save $8,000,000 capital investment, 64,500 tons steel, and reduce transmission costs 0·8c/1000 cu. ft. E. B.

2650. Welding in pipe-line construction. H. Jansen. *Erdöl u. Kohle*, 1952, **5**, 350–7.—Present-day pipe-welding technique is discussed, with particular reference to German standards. Butt and lap joints are described and field of application of each type considered; numerous illustrations. Importance of correct heat treatment of welded joint is stressed, and improvement of metal structure by such procedure (Keel's process) is illustrated by photo-micrographs showing increased grain fineness, resulting in better notch impact resistance. V. B.

2651. Maracaibo lake oil drilling barge. Anon. *Fluid Handling*, June 1952 (29), 169–72.—A diesel electric power and supplies barge of 2545 tons displacement is to be used in conjunction with a piled steel structure at each well site. It has been designed to carry well casing and drill piping, drilling mud, dry mud and barytes, fuel and lubricants, water and miscellaneous supplies, operating for over thirty days at up to 15 miles offshore.

Full details are given of the power generating plant, motors, pumps, and construction of the vessel. D. H.

2652. Standard storage tanks. E. A. Reynolds and M. J. Noone. *Proc. 3rd World Petrol. Congr.*, 1951, **8**, 111–45.—Paper in seven sections dealing with arguments in favour of an internationally recognized standard for tanks. Section I outlines place of storage tank in industry; Section II discusses present position of standardization; Section III lists differences between American and European standards; Section IV discusses these differences and conclusions drawn lead to proposed standard; Section V defines standard tank proposed, including notes on materials, fabrication, etc., illustrated by drawings; Section VI covers future design and construction trends; Section VII gives references to published and unpublished work. E. J. C.

2653. Feasibility of underground storage studied by N.P.C. committee. Anon. *World Petrol.*, 1952, **23** (7), 40.—Costs of surface pressure and atmospheric storage of pet products in terms of total cost per brl are $20 and $1·09 respectively, compared with $0·75 and $4·80 per brl for storage in dissolved salt and in mined cavities (100,000 brl basis). Savings in steel and manpower are substantial for underground storage. Recommendations are made for design, safety precautions, and location of underground reservoirs. E. B.

2654. Underground oil storage proved practical in Sweden. R. L. Simons. *World Petrol.*, 1952, **23** (7), 38–9.—Successful underground storage in old mines and specially excavated reservoirs was achieved by locating the cavities below the upper level of sub-soil water of sufficient pressure to prevent oil migration. A water layer is maintained and raised or lowered to keep oil level suitable for pumps. Method of storage reduces fuel costs because of good heat insulation. No mixing of oil and water occurs. System has been extended to gasoline and other light oil storage, and bottle-shaped cavities have been blasted out of rock. Evaporation losses and fire risk are greatly reduced, and colour of gasoline is stable. Initial cost of 100,000 to 1,000,000 cu. ft. tanks are higher than for steel surface tanks, but maintenance costs are 30 to 40% lower, largely due to reduced evaporation loss and lower insurance rates. E. B.

2655. Conservation of products in storage. S. S. Smith and G. D. Harden. *Oil Gas J.*, 14.7.52, **51** (10), 125; *Refiner*, July 1952, **31** (7), 151–3.—From the study of evaporation losses from 50-gal drums, painted various colours, from 1000-gal tanks, also of various colours, and from one test on a 80,000-brl cone-roof tank, it is concluded that the most effective coating for storage vessels is a white paint for roof and side walls. A net saving of $1500 per year per tank, after paying for paint, is shown. G. A. C.

Refinery Operations

Refineries and Auxiliary Refinery Plant

2656. Design of gasoline plants. Pt 5. Pipe selection. O. L. Lewis. *Petrol. Engr*, June 1952, **24** (6), C22–6. **Pt. 6. Selection of pipe fittings.** July 1952, **24** (7), C34–85. (Cf. Abs. 956, 1603.)—Pts 3 and 4 of the series dealt with general principles for layout of piping and the positioning of piping details respectively. Pt 5 outlines the various standard specifications governing the selection of pipe for various services and gives a useful method of ensuring the correct choice of pipe for the required purpose. Factors considered when selecting pipe materials are pressure and temp, joint efficiency, allowable stress, and wall thickness. Allowable working pressures are tabulated for pipe sizes ¼-inch I.D. to 24-inches O.D. for various conditions based on the ASA Code for Pressure Piping B—31.1.1951, Sect 3, Divn A.

Pt 6 details types and sizes of pipe fittings suitable for particular services. Plots of cost against pipe size are given for tees, welding tees, and elbows of various types. Emphasis is laid on the advantage of simplicity and standardization within the plant.

E. K. J.

2657. Limited water supply dictates equipment choice for gasoline plant. Anon. *Refiner*, July 1952, **31** (7), 130.—The recently completed Ringwood gasoline plant employs certain equipment features to minimize the water consumption. These include the elimination of steam power and the use of aerial coolers and direct-fired rich oil furnaces. A. R. H.

2658. Coryton oil refinery. Anon. *Engineer*, 1952, **193**, 605–6.—Vacuum Oil Co's new refinery at Coryton, Essex, is expected to be completed by 1953. It will cost £10 million and have a throughput of 850,000 tons p.a. Crude oil is distilled in two-stage atm and vac unit, S.R. naphtha is thermally reformed, gas oil "Thermofor" cat cracked. Lub oils produced by furfural refining and M.E.K. dewaxing; finishing process for both oils and waxes being percolation. Cooling water intake is from Thames at 45 million g.p.d. Tanker jetty will accommodate 32,000-ton vessels. Scheme includes all steam and power generation requirements. A. C.

2659. Kent oil refinery. Anon. *Engineer*, 1952, **193**, 671–4.—Anglo-Iranian Oil Co's subsidiary, Kent Oil Refinery Ltd., is constructing a new refinery on the Isle of Grain, part of which is scheduled for production in July 1952. Final capacity is 4 million tons p.a., and total estimated cost £40 million. Products (tons annually) will be 965,000 motor spirit, 110,000 kerosine, 29,000 tractor vaporizing oil, 490,000 gas oil, 1,862,000 fuel oil, 140,000 lub oil. Processes include atm and vac dist, copper chloride sweetening of motor spirit, SO_2 extraction of kerosine, cat cracking of vac dist with acid treatment and re-running of heavy cracked gasoline. Cooling water at 4 million g.p.h. will be pumped from Medway estuary and returned ¾ mile downstream at max temp of 110° F. Most of power requirement will be generated with steam at 550 p.s.i.g. Four new tanker jetties will accommodate 32,000-ton vessels. A. C.

2660. How Derby gained flexibility with its new air-lift T.C.C. D. P. Thornton. *Petrol. Process.*, 1952, **7**, 815–17.—The modernization programme recently completed at the Wichita, Kansas, refinery of Derby Oil Co. is reviewed. Brief descriptions with flow diagrams are given of the enlarged crude unit and the new Thermofor cracking unit. To the old crude unit a new heater and primary tower have been added, the original tower being made the secondary of the 15,000-b.d. two column distillation unit.

The principal design features and operation of the air-lift T.C.C. unit are mentioned. By handling both vapour and liquid feeds if necessary, considerable flexibility of operation is obtained with this otherwise standard unit. Rated charge for 50% conversion is 8000 b.d. gas oil or 4000 b.d. with 3600 b.d. recycle for 75 to 80% conversion. Yield data are given for the start-up and normal operation. Gas recovery and phosphoric acid polymerization facilities have also been extended. D. W. F.

2661. How the platformer is applied to Eastern States operation. Anon. *Refiner*, June 1952, **31** (6), 144.—A brief description of the operation of the platformer at Houston is presented with a flow diagram. A. R. H.

2662. Shell completes post-war expansion programme in United Kingdom. V. S. Swaminathan. *Refiner*, June 1952, **31** (6), 124–5.—The new cat cracker at Stanlow is now in operation, and produces over 1,000,000 tons per year. The light products are separated into five fractions, light gases containing hydrogen, methane, ethane, and ethylene; three streams containing 3, 4, and 5 carbon atoms respectively, and a gasoline fraction. The C_3 and C_4 streams are converted to alcohols and ketones. About 10,000 tons/annum of sulphur are recovered in the sulphur recovery unit. A. R. H.

2663. Montreal refinery. Anon. *Petroleum*, Aug. 1952, **15** (8), 217–18.—Surveys new extensions to the Shell Oil Co. refinery in Quebec, which include a new type of cat cracking plant, an in-line blending plant unique in Canada, and new topping, polymerization, and vacuum flashing units which increase the refinery capacity five times. The refinery can now process 25,000 b.d. of crude; the combined yield of all units on an average day is 440,000 gal of gasoline, 280,000 gal of distillate fuels, 145,000 gal of heavy fuel oil, 30,000 gal of naphthas, and 18,000 gal of L.P.G. R. E. P.

2664. Pumoridge pump index. Anon. *Fluid Handling*, June 1952 (29), 180–1, 188.—(Cf. Abs. 2327—1951.) Bofec-Fielding Slush, Edwards Speedivac Rotary Vacuum, Lister Deep Well, Lister Shallow Well, Moorlands Duplex, Pearn Single Ram N, NM, NG, NGM. July 1952 (30), 212–13, 220.—Auto-diesels self-priming, Gwynnestar, Mopump OC, VL, VH, Pearn twin ram, Whittaker Hall hydraulic. Aug. 1952 (31), 245–6, 252.—Ejectopump B 3 SV, Godwin jet J 3B, J 3D, Keelavite hydraulic gear G and GH, Peran dry Vacuum, Pegson Marlow lightweight mudhog, Savery rotary, Speedivac combined compressor and vacuum pump. D. H.

2665. Engineering reference section. G. L. Farrar. *Oil Gas J.*, 14.7.51, **51** (10), 131; 21.7.52, **51** (11), 105.—Pt 14 of this series deals with trouble shooting in pumps, and shows how to locate troubles in centrifugal and rotary pumps by analysis.

Pt 15 deals with inspection of pumps for corrosion to ensure safety. Two specific cases illustrate developments of hazardous conditions due to wrong material and methods. G. A. C.

2666. Engineering reference section. L. B. Woolfenden and R. C. Thiede. *Oil Gas J.*, 4.8.52, **51** (13), 101.—Pt 16 deals with pump designing for maintenance, and gives experience with closed coupled units. G. A. C.

2667. Refiner's notebook. C. A. Dally. *Oil Gas J.*, 4.8.52, **51** (13), 105.—No. 132 deals with operating characteristics, design, and application limitations of butterfly valves.

A figure shows operating torque characteristics for a 10-inch dia butterfly valve with 1 p.s.i. pressure drop. G. A. C.

2668. Thermal insulation for industrial requirements. R. Thomas. *Refiner*, June 1952, **31** (6), 113–16; July, 1952, **31** (7), 145–9.—In Pt IV the design considerations for insulation for the atmospheric temp range are discussed.

Pt V deals with the specifications and application of insulating materials for use in the atmospheric temp range, 32° to 212° F. A. R. H.

2669. New type distillation, absorption and extraction column. M. R. Cannon. *Oil Gas J.*, 28.7.52, **57** (12), 268.—A jet contactor to provide more intimate mixing of liquid and vapour on trays in columns used for separation processes is described. Liquid and vapour are mixed in a high velocity tube to give a high degree of turbulence, causing an increase in rate of mass transfer and destruction of any areas of localized turbulence. G. A. C.

2670. How to clean slurry exchangers. W. M. Zingg and B. P. Robinson. *Petrol. Process.*, 1952, **7**, 826–7.—Mention is made of the nature of deposits likely to be found on the shell side of slurry exchangers used for preheating reactor feed charge on catalytic cracking units. In cases where it is not convenient to remove the bundle for cleaning chemical cleaning is suitable, using hot hydrocarbons and alkaline solution mixtures, followed by inhibited acid base solvents. D. W. F.

2671. Application and comparison of various types of cooling equipment. J. G. De Flon. *Proc. 3rd World Petrol. Congr.*, 1951, **8**, 190–207.—Discusses industrial cooling equipment, including spray ponds, atmospheric cooling towers, forced draught towers, natural draught coolers, and air-cooled exchangers. E. J. C.

2672. Transmission of heat without walls. J. L. Barbouteau and H. Poisson. *Proc. 3rd World Petrol. Congr.*, 1951, **8**, 208–21. (In French).—Discusses cooling and condensing of petroleum products by direct contact with water. Method is illustrated by a laboratory apparatus, and industrial applications are described, together with some operating data and calculations. E. J. C.

2673. Progress made in the manufacture of furnace tubes. J. Dauvergne. *Proc. 3rd World Petrol. Congr.*, 1951, **8**, 1–12. (In French.)—Describes progress made in France in the manufacture of furnace tubes, of all grades, and indicates that French tube mills are capable of supplying all the demands of their petroleum customers. E. J. C.

2674. Ferrous metal tubing in refining processes. H. B. Newdell and J. J. B. Rutherford. *Proc. 3rd World Petrol. Congr.*, 1951, **8**, 13–14.—Discusses properties of carbon and alloy tubes for the oil industry. E. J. C.

2675. Unfired pressure vessels for the petroleum industry. W. Samans. *Proc. 3rd World Petrol. Congr.*, 1951, **8**, 169–88.—Design of steel and alloy pressure vessels is reviewed with illustrations of such specific items as early high pressure vessels, fractionating columns, and more recent developments. E. J. C.

2676. Welding of metals important to the petroleum industry. H. G. Geerlings and C. Vollers. *Proc. 3rd World Petrol. Congr.*, 1951, **8**, 15–31.—" Weldability " of metals is defined and a test described for determining this property, a welded joint being subjected to the Ericksen cup test. Factors are studied which limit the welding of Cr–Mo steels, and the possibility of facilitating welding by use of austenitic electrodes is discussed. In this connexion a spectrographic analysis was made to determine the extent of dilution of weld metal with base metal. Results are given graphically. Structural changes of metals during service at high temp are discussed, and a brief survey made of problems connected with the welding of non-ferrous metals. E. J. C.

2677. Evaluation of radiant heat absorption ratio in tubular heaters. Pt 1. L. A. Mikler and R. S. Fairall. *Refiner*, June 1952, **31** (6), 101–7.—Graphical methods are presented for the solution of radiant heat transfer problems in the design of pipe stills. Radiation from primary sources is considered. A. R. H.

2678. New stress calculations and temperature curves for integral flanges. W. P. Kerkhof. *Proc. 3rd World Petrol. Congr.*, 1951, **8**, 146–67.—Describes a new method for performing stress calculations in integral flanges, the results being compared with full-scale tests. Text is supported by plotted and tabulated data, and a sample calculation is worked out. E. J. C.

2679. Mechanical seals in the petroleum industry. F. B. Porges. *Proc. 3rd World Petrol. Congr.*, 1951, **8**, 222–34.—Description of main types of mechanical seals used for pumping requirements of petroleum industry with reference to drawings. Some cost data given. Eleven references to important papers. E. J. C.

2680. Performance of the propane refrigeration system using centrifugal compressors. T. T. Whipple and I. Taylor. *Proc. 3rd World Petrol. Congr.*, 1951, **8**, 242–51.—Review of initial operating experience, system design, and compressor selection for several propane refrigeration systems served to emphasize the importance of determining early in plant design the anticipated partial load operations.

Operating experience is reported to show such systems to be dependable and satisfactory for providing refrigeration. E. J. C.

2681. How to design and operate refinery flares. D. L. Cleveland, W. G. Green, E. P. Kropp, and W. H. Smolen. *Oil Gas J.*, 4.8.52, **51** (13), 52.—Waste gas flares must burn without smoke, have a wide capacity as to gas rate and B.Th.U. content, have positive ignition and good flame stability.

Four sections deal respectively with steam inspirating flares, venturi type aspirating burners, improved flare tips; and a successful ground flare is described. A discussion on the articles is also reported. G. A. C.

2682. Quick reading flow sheets. W. L. Willoughby. *Oil Gas J.*, 21.7.52, **51** (11), 81.—Typical flow sheets and diagrams are too detailed. Six methods by which they may be simplified are shown, and wrong way illustrated. G. A. C.

2683. Friction coefficient of rough pipes. J. R. Finniecome. *Mech. World*, July 1952, **132** (3396), 37.—The experimental values of the coefficient of friction in rough pipes as ascertained by various investigators are examined. Numerous tables and graphs are included. T. T.

2684. How Sohio fights air pollution. E. P. Kropp and R. N. Simonsen. *Oil Gas J.*, 21.7.52, **51** (11), 84.—A pilot model fog filter type scrubber at the Cleveland refinery has proved use of this type unit for removal of fatty acid odour, and for absorption of SO_2 and H_2S from air streams containing these contaminants. The Standard Oil Co. are installing commercial fog filter units at Cleveland as a result of these experiments.

Tables show experimental results and operating conditions. G. A. C.

2685. Refiner's notebook. S. Chesler and B. W. Jesser. *Oil Gas J.*, 14.7.51, **51** (10), 135; 21.7.52, **51** (11), 109.—No. 130 deals with diffusion in design of open discharge systems. Figures show effect of moderate stack velocity on smoke pattern, and anticipated effect of high stack velocity on gas discharge from relief valves.

No. 131 considers some of the factors in applying diffusion equations to design of open relief valve discharge systems. Factors include stack velocity, density, and effect of diluents. G. A. C.

Distillation

2686. Fractionation calculations made easier and faster. E. N. Pennington, F. H. Poetmann, and K. H. Hachmuth. *Refiner*, July 1952, **31** (7), 103. (*NGAA convention Houston, Apr.* 1952.)—A method is presented for fractionation calculations based on the usual assumptions of constant molal overflow and constant relative volatility. It is applicable to multicomponent fractionation problems, and the results compare favourably with those obtained by the conventional stepwise method. It also enables the determination of the location of the feed plate. Specimen calculations are given. A. R. H.

2687. Faster fractionator design methods developed by Phillips Petroleum. Anon. *Petrol. Process.*, 1952, **7**, 818–19.—Summaries are published of four papers presented at the "Forum on extraction and separation calculations" held during the annual meeting, *Nat. Gasoline Assn of America, Houston*, 30 *Apr.*–2 *May* 1952. Papers are: "Fractionation calculations using constant volatility ratio," by E. N. Pennington, F. H. Poettmann, and K. H. Hachmuth; "Development of theory and charts for absorption and stripping factor methods," "Fractionator calculations by the absorption and stripping factor method," both by R. L. McIntire, R. O. Shelton, and K. H.

Hachmuth; "Absorption and stripping factors method applied to absorbers, stills and similar equipment," by B. J. Ferro, H. R. Legatski, and K. H. Hachmuth.
D. W. F.

2688. Solution of multicomponent phase equilibria problems. C. L. Wilson. *Refiner*, June 1952, **31** (6), 131–8.—A simple graphical method is presented for estimating flash vaporization reducing the number of trials required by the more precise methods. The basic mathematics and previous calculation methods are reviewed. A. R. H.

2689. Characterization of petroleum residuums by vacuum flashing. P. H. Johnson and K. L. Mills, Jr. *Industr. Engng Chem.*, 1952, **44**, 1624–9.—A vacuum flash unit and procedure are described for obtaining flash data on four topped crudes. Data are tabulated and plotted. E. J. C.

2690. Patents. Ger.P. 838,745, 3.4.52. E. Curland, J. Schroeter, and H. Umbach, assrs to Kohlentechnik G.m.b.H. Column for deacidification and desulphurization of ammonia water.

Ger.P. 837,844, 27.3.52. F. Lampe, assr to Bad. Anilin- & Soda-Fabr. Supporting device for plates in dist and rectification columns, washing towers, and similar apparatus.

Ger.P. 837,845, 27.3.52. N. H. Nordenborg, Karlstadt, Sweden. Procedure and apparatus for fractional dist.

Ger.P. 847,846, 27.3.52. E. Rieger, Wyhlen, Baden. Dist apparatus with stepped juxtaposed exchange plates.

Ger.P. 839,190, 10.4.52. H. Baumgartner, assr to Patelhold A.G., Glarus, Switzerland. Procedure and apparatus for vaporization of liquids.
Brennstoff-Chem., 14.5.52, **33** (9–10). R. T.

Absorption and Adsorption

2691. Have you solved these absorption plant problems? R. L. Lane and B. J. Thompson. *Refiner*, June 1952, **31** (6), 120–3. (*Absorption and dry distillation 31st Ann Convention, Natural Gasoline Ass. of America. Houston, 1 May* 1952.)—Methods for combating entrainment, foaming, temp rise, and overload in absorption units are discussed, and methods of stripping rich oil with hydrocarbon vapours are described. A. R. H.

2692. Analytical solution for simple systems in moving bed adsorbers. P. R. Kasten and N. R. Amundson. *Industr. Engng Chem.*, 1952, **44**, 1704–11.—The theoretical aspects of adsorption processes employing moving beds, such as hypersorption process, are dealt with mathematically, and the equations are applied to the solution of a practical problem involving the removal of C_6H_6 vapour from air. E. J. C.

2693. Selective adsorption of hydrocarbons. Pt 1. G. Spengler and K. Krinkler. *Refiner*, July 1952, **31** (7), 111–14.—(See Abs. 1280—1950.) A. R. H.

2694. Effect of intraparticle diffusion-agitated non-flow adsorption systems. F. J. Edeskuty and N. R. Amundson. *Industr. Engng Chem.*, 1952, **44**, 1698–703.—A theoretical analysis is presented for the adsorption of a solute on to a solid adsorbent from a solution. The theoretical equations were confirmed by a series of experiments in which activated carbon was used to remove phenol from water. Data are tabulated and plotted. E. J. C.

2695. Arosorb process in refining operations. W. H. Davis, J. I. Harper, and E. R. Weatherley. *Petrol. Engr*, June 1952, **24** (6), C5–8.—(See Abs. 2080.)

2696. Liquid recovery from hydrocarbon gases. T. H. Anderson, Jr. and W. E. Colburn. *Petrol. Engr*, June 1952, **24** (6), C28–35.—Four basic methods of liquid recovery from wet gases are: (1) adsorption, (2) condensate fractionation, (3) gas

fractionation, and (4) absorption and the relative merits of each process are considered with reference to a particular example for processing 24 million cu. ft/day of wet gas.
E. K. J.

Solvent Extraction and Dewaxing

2697. Ternary liquid systems. C. M. Oualline, Jr., and M. Van Winkle. *Industr. Engng Chem.*, 1952, **44**, 1668–70.—Equilibrium data at 25° C are reported for the systems 3-heptanol–water–acetic acid and 3-heptanol–water–ethyl alcohol.
E. J. C.

Cracking

2698. Bench-scale cracking unit reproduces plant conditions. C. W. Rackley and C. W. Shelley. *Refiner*, June 1952, **31** (6), 89–92.—A small fixed-bed cracking plant is described which closely reproduces large scale pilot and commercial plant data. The unit has a charge capacity of 500 ml, and full evaluations may be made by using micro-methods for testing the products.
A. R. H.

2699. Catarole process produces high yield of olefin gas and aromatics. Anon. *Refiner*, July 1952, **31** (7), 154–5.—The Catarole process is a high temp cracking process which produces a high yield of gaseous olefins and a liquid product which is predominantly aromatic in character, permitting separation into pure products. A commercial plant in operation at Petro-chemicals Ltd., Manchester, operating at 1290° F and 20 to 50 p.s.i. is briefly described.
A. R. H.

2700. Houdriforming—its place in the refining of petroleum. T. A. Burtis and H. D. Noll. *Petrol. Engr*, June 1952, **24** (6), C39–44.—The economics of unit construction and process operation are analysed on the basis of the pilot plant data for the process operating on East Texas crude. The analysis is applied to two refineries of 10,000 b.d. capacity with thermal cracking and Houdriflow recycle, catalytic cracking respectively. Each refinery is considered with either thermal reforming or Houdriforming, the latter process being operated at each of two severity levels. The economic summary is presented for the cases outlined based on typical refinery operation, and shows the advantage of higher investment cost for the catalytic process in terms of profit after five years operation.

The results of pilot plant processing of five charge stocks are tabulated, and yield–O.N. curves given for each stock shows that the process is not of limited application. The advantages of Houdriforming are summarized as: (1) upgrading heavy naphthas for motor fuel; (2) desulphurization and octane improvement of high sulphur stocks; (3) processing of selected cuts for aromatics.
E. K. J.

2701. Thermofor catalytic reforming (T.C.R.). J. W. Payne, L. P. Evans, E. V. Bergstrom, and V. O. Bowles. *Petrol. Engr*, June 1952, **24** (6), C10–20. (*API mtng, San Francisco, May* 1952.)—The T.C.R. process is reported as an economical method of improving O.N.s of straight-run and thermally cracked stocks with corresponding low butane yields and almost complete removal of sulphur as hydrogen sulphide in the make gas. Three years pilot plant work at Socony-Vacuum laboratories, New Jersey on a 50-b.d. moving bed unit has resulted in the design of commercial units up to 20,000 b.d. Ten different types of stock were processed, properties and yields for five charge stocks are tabulated. Recycle gas is dried to avoid excessive moisture in the reaction zone which reduces product yields. Lubricated plug valves with stellited surfaces were found most satisfactory for the catalyst transfer system. Loss of catalyst activity equivalent to 2% lower gasoline yield at a given O.N. was found after eighteen months operation. Hydrogen enrichment was not found necessary but provision for removal of *c* 1% polymer was made.

The catalyst, a synthetic chromia–alumina gel in bead form, permits reforming to high O.N. with good yields, has low operating hydrogen partial pressure, is easily regenerated, promotes excellent desulphurization, and has high physical strength and ruggedness.

Details are given of the process and mechanical design of commercial units based on the results of pilot plant operation. Operating conditions were found to be largely independent of feed stock properties. The final selected design was a single reactor, without reheat, using a recycle gas to naphtha ratio of 6 : 1 and operating at a pressure of 175 p.s.i.g., a space velocity of 0·7 with an average reactor temp of 1000° F for reforming to an octane rating of 100 with 3 ml/gal T.E.L. addition. The economics of the process are analysed for a 30,000-b.d. refinery, and by comparison with thermal reforming are shown to be appreciably in favour of T.C.R. E. K. J.

2702. Turnaround of a combination unit. G. Weber. *Oil Gas J.*, 14.7.52, **51** (10), 119.—An example of frequent turnaround of a thermal cracking unit at Whiting refinery of Standard Oil Co., Indiana, is given. Work is done after careful planning and co-ordination, in from ten days to two weeks. Detailed records of each turnaround are kept. G. A. C.

2703. First package type T.C.C. unit operation successful. C. L. Withers. *Petrol. Engr*, July 1952, **24** (7), C7–10; *Refiner*, July 1952, **31** (7), 1224.—(See Abs. 23-2.) E. K. J.

2704. Preparation of aromatic compounds from petroleum fractions. V. Berti. *Riv. Comb.*, 1952, **6**, 225–47.—The present Italian demand for light hydrocarbons (benzene, toluene, and xylenes) considerably exceeds the production possibilities from coal distillation. It is therefore necessary to produce aromatic compounds from petroleum fractions by means of thermal or thermocatalytic treatments. These treatments can be divided into two types : (1) processes carried out at low temp and at medium and high pressure (hydroforming, platforming, Houdriforming, etc.), and (2) processes carried out at high temp and low pressure (Catarole, T.P.C., steam-cracking, etc.).

The gaseous paraffinic hydrocarbons (methane, ethane, propane, and butane) also give aromatics at high temp. The chief reactions that take place are reported in detail and the results obtained with some operations.

Finally, the following fundamental methods of aromatic compounds extraction are described—selective extraction in liquid/liquid phase ; extraction in liquid/vapour phase ; azeotropic distillation ; selective adsorption. Ten references. (Author's Summary.)

2705. Progress made in design of catalyst activity testing units. F. E. Ivey, Jr., and P. L. Veltman. *Refiner*, June 1952, **31** (6), 93–100.—A standard test is required for the assessment of catalyst activity. The test methods already in use are discussed, and it is shown that the precision of all these methods is poor. A new apparatus has been constructed and is described in detail, thermal pre-treatment and steam deactivation tests have been carried out and the results analysed statistically. It is shown that the precision is considerably greater than that obtained in previous methods and the unit is more flexible, but further improvement in the thermal pre-treating equipment would probably give even better precision. A. R. H.

2706. Patents. Ger.P. 840,390, 17.4.52. F. Schnur, assr to Ruhrchemie. Process and arrangement for fractional cooling of contact furnaces.

Ger.P. 837,992, 27.3.52. W. Flesch and P. Feiler, assrs. to Bad. Anilin- & Soda-Fabr. Process for cracking gaseous or liq hydrocarbons or materials containing hydrocarbons.

Ger.P. 839,638, 10.4.52. G. Steuler, assr to Steuler-Indust-Werke Höhr-Grenzenhausen. Reaction chamber for strongly exothermic chem-physical reactions.

Ger.P. 838,598, 3.4.52. H. G. Kayser and W. Herbert, assrs to Metallges. A.G. Process and arrangement for exothermic cat reactions in contact furnaces.

Ger.P. 839,035, 10.4.52. W. F. Engel, assr to N.V. de Bataafsche Petroleum Mij. Procedure for production of cast cat masses of great mechanical strength.

Brennstoff-Chem., 14.5.52, **33** (9–10). R. T.

Hydrogenation

2707. Patents. Ger.P. 839,936, 17.4.52. W. Oettinger, H. v. Füner, and H. Nonnenmacher, assrs to Bad. Anilin & Soda-Fabr. Process for dehydrogenation of naphthenic hydrocarbons.

Ger.P. 837,994, 27.3.52. H. Lucke, Heidelberg. Method for production of synthetic, especially knockproof fuels and lubricants by cat hydrogenation under pressure.
Brennstoff-Chem., 14.5.52, **33** (9–10). R. T.

Chemical and Physical Refining

2708. Colour formation in copper chloride-sweetened distillates. J. H. Krause and T. B. Tom. *Industr. Engng Chem.*, 1952, **44**, 1603–6.—Procedure reported by which colour stability of copper chloride-sweetened distillates could be determined after batch or continuous treatments. Undesirable components were isolated from the virgin stocks by extraction and adsorption methods. Phenolic compounds were found to be particularly detrimental to colour stability, amines were less detrimental, and disulphides and cyclic sulphides were essentially inactive as far as colour was concerned. Trace amounts of oil-soluble copper compounds also catalysed colour formation, but the effect could be removed by hot water washing. E. J. C.

2709. Lube oil acid treatment developed for Italian refineries. F. Sager and F. Palmqvist. *Refiner*, June 1952, **31** (6), 139–43.—The history of the Italian oil industry is briefly outlined.

The new acid treatment is a short contact centrifugal process. Oil is mixed with acid in a mixing pump and passes through contact columns, the time of contact being not longer than a few minutes to avoid chemical reaction. The oil is then separated in a centrifuge and passes to an air agitator tank. Last traces of acid are removed by another centrifuge. Data showing the effect of contact time, temp, and acid concentration on product quality are presented. A. R. H.

2710. Stringent specifications met by highly refined petroleum oils. G. Cibula. *Refiner*, July 1952, **31** (7), 131–3.—(See Abs. 2784—1950.) A. R. H.

2711. Desulphurization process developed by Anglo-Iranian. Anon. *Refiner*, June 1952, **31** (6), 108–9; *Petrol. Engr*, July 1952, **24** (7), C31–2.—(See Abs. 2349.) A. R. H.

2712. Patent. Ger.P. 839,193, 10.4.52. R. Heinrich, assr to Metallges. A.G. Process for electrical separation of fine dust from gases.
Brennstoff-Chem., 14.5.52, **33** (9–10). R. T.

Special Processes

2713. Alcohols derived from olefins. Anon. *Industr. Chem.*, 1952, **28**, 306–7.—At British Petroleum Chemicals Ltd., Grangemouth, Middle East naphtha of boiling range 100° to 200° C is cracked at 1325° F with steam injection. Ethylene and propylene are formed, and are fractionated from other products of cracking by dist at high pressure and low temp. Ethylene is cat reacted with water at high pressure to produce ethyl alcohol, which is scrubbed and fractionated to 92·4% purity. By reacting propylene with 75% sulphuric acid at 350 p.s.i., hydrolysis of the propyl hydrogen sulphate, and subsequent fractionation, 85% *iso*propyl alcohol is produced. A. C.

2714. Extractive crystallization—a new separation process. Pt 3. K. A. Kobe and W. G. Domask. *Refiner*, July 1952, **31** (7), 125–9.—(Cf. Abs. 1679, 2128.) The practical applications of urea and thiourea adduct formation are discussed, including analytical applications, the separation of hydrocarbons, and the separation of fatty acids. A. R. H.

2715. Gas for Calgary from sulphur recovery. H. C. Plummer. *Petrol. Engr*, June 1952, **24** (6), C51–4.—25 million cu. ft/day of gas will be processed at Jumping Pond, Alberta, and throughput is likely to be doubled. The sulphur recovery plant is designed to produce 30 long tons/day of 99·9% purity sulphur. Scrubbed gas is delivered by pipeline to the city of Calgary. The sulphur is recovered by partial combustion of H_2S and then catalytic conversion of H_2S and SO_2 to elemental sulphur in two stages using aluminium oxide or natural bauxite catalyst. Gases from second stage are scrubbed by liquid sulphur, which is recycled and product is withdrawn from recycle stream. Sulphur is completely removed from the gas stream due to the low vapour pressure of sulphur at the exit temp. E. K. J.

2716. Petrochemicals from water gas. Pt 3. P. W. Sherwood. *Petrol. Engr*, July 1952, **24** (7), C13–18.—(Cf. Abs. 2103.) The processes for production of hydrocarbons by coal hydrogenation and gas synthesis are described. Details are also given of the Synol synthesis for production of long-chain alcohols and of the OXO synthesis for production of long-chain aldehydes and alcohols. The commercial applications are outlined with operating details of the processes. E. K. J.

2717. Petrochemicals in T.E.L. manufacture. D. P. Thornton. *Petrol. Process.*, 1952, **7**, 846–8.—A brief description is given of the Ethyl Corp's T.E.L. plant at Houston, which has recently commenced operation. Capacity is believed to be around 2,250,000 lb/day T.E.L. Production is split into three main areas, sodium, ethyl chloride, and T.E.L. In the first pure salt, obtained from brine, plus a little calcium chloride is electrolysed at 1100° F to produce sodium metal and chlorine. The chlorine is purified and compressed to 30 p.s.i. and piped to the ethyl chloride area to form hydrogen chloride and ethylene dichloride. Ethyl chloride is synthesized from ethylene and hydrogen chloride catalysed with aluminium chloride. In the T.E.L. area the sodium is alloyed with pure lead, which is mixed with ethyl chloride in autoclaves to produce T.E.L. The ethylene dichloride is used in the final T.E.L. motor mix to inhibit the decomposition of the T.E.L. itself. D. W. F.

2718. Reactions of hydrogen and carbon monoxide. W. M. Campbell and H. F. Johnstone. *Industr. Engng Chem.*, 1952, **44**, 1570–5.—The Fischer–Tropsch reactions were studied under highly simplified conditions using a porous tube impregnated with an iron–copper catalyst. The close control of temp and simplicity of sampling along the reactor provide an opportunity to study the abrupt changes when the composition of the gas is altered or an inhibitor is added. Most of the catalysts used produced carbon dioxide and were active for the water gas shift reaction. Heating catalysts to 310° C in presence of H_2 and CO destroyed the synthesis reaction activity, but did not affect the shift reaction activity. H_2S destroyed the activity for both reactions. The shift reaction activity of a water-producing catalyst was increased by increasing the hydrogen concentration in the feed gas. These results indicate that two types of active centres exist, one active for the shift reaction and the other active for the synthesis reaction. Actual reaction mechanism is proposed by which paraffins are formed by the termination of a chain by hydrogenation, and olefins are formed by splitting the $(CH_2)_n$ chain off the surface. (Authors' abstract.) E. J. C.

2719. Patents. Ger.P. 835,175, 28.2.52. E. Schön, assr to Dr C. Otto and Co. Process for washing naphthalene from coke oven gas.

Ger.P. 836,693, 13.3.52. P. J. Haringhuizen, assr to Staatsmijnen. Process for separating the ethylene fraction from coke oven gas.
Brennstoff-Chem., 1952, **33** (7–8).

Ger.P. 839,346, 10.4.52. F. Markert, assr to Bad. Anilin- & Soda-Fabr. Arrangement for conversion of CO with steam to CO_2 and H_2.

Ger.P. 839,347, 10.4.52. F. Markert, assr to Bad. Anilin- & Soda-Fabr. Procedure for conversion of CO with steam to H_2 and CO_2.

Ger.P. 840,838, 24.4.52. K. Keller, assr to Kohlentechnik G.m.b.H. Process for recovery of halogen hydrocarbons from gases containing them.

Ger.P. 837,847, 27.3.52. K. Büchner and P. J. Kühnel, assrs to Ruhrchemie. Procedure for cat addition of water gas to unsaturated hydrocarbons.

Ger.P. 840,237, 17.4.52. G. Free, assr to Bad. Anilin- & Soda-Fabr. Method for production of gaseous unsaturated, and of aromatic hydrocarbons.
Brennstoff-Chem., 14.5.52, **33** (9–10). R. T.

Metering and Control

2720. Cit-Con whips lube plant instrumentation problems. E. W. Midlam and J. D. Dorsey. *Refiner*, July 1952, **31** (7), 137–40. (*Symp. for Process Industries, College Station, Texas, June* 1952.)—Instrumentation used to control the pressure in a distillation system where propane is flashed from 250 to 70 p.s.i. is described. The load on three compressors is controlled by the pressure in the distillation columns. A case of over-instrumentation was experienced in a water removal tower in the solvent recovery section of a furfural plant. Steam injected to the column was controlled by the temp near the top, but hand control was found to be much more satisfactory due to the constant boiling characteristics of the mixture.

The charge to the chillers of a solvent dewaxing plant is controlled by the pressure at the chiller inlet rather than by flow controller to guard against plugging the chillers. Pressure and flow control was used on a propane centrifugal compressor unit to guard against "puffing." A. R. H.

2721. Variable aperture and shunt type flowmeters. Pt III. A. Linford. *Fluid Handling*, July 1952 (30), 209–11.—The tapered-tube-and-disk type of meter is compared with the hinged gate type for accuracy, capacity, and flow resistance. Two shunt-type meters are described. A construction in the main flow line develops a small pressure difference, which is measured indirectly in a small by-pass line. D. H.

2722. Flow-meter and pressure indicator for gases. Anon. *Brennstoff-Chem.*, 1952, **33** (9–10), 185.—An apparatus is described and illustrated which measures immediately at temp up to 1000° C, at low pressures to 5000 mm w.g. and excess pressures up to 6 atm in heavily dust-laden flow. The min measuring ranges are 0 to 0·5 m/sec or 0 to 0·03 mm w.g. or 0 to 1 l/min the max ranges include flows of 0 to 100 m/sec or 0 to 600 mm w.g. and unlimited quantity measuring ranges. R. T.

2723. Orifice-meter coefficients for large diameter lines. F. L. Resen. *Oil Gas J.*, 28.7.52, **51** (12), 288.—A committee composed of members of the American Gas Association, American Society of Mechanical Engineers, and National Bureau of Standards has been set up to investigate measurement of gas flow through 10- and 30-inch lines. Main problem is to find coeffs for the larger size meters. G. A. C.

2724. New light on use of graphic panels. J. Weingartner. *Oil Gas J.*, 28.7.52, **51** (12), 334.—The advantages of graphic panels and miniature instruments are pointed out, especially in view of increased processing activity.

Semi-graphic and full graphic panels are illustrated. G. A. C.

2725. Technical control in refineries. A. Major. *Nafta*, 1951, **7**, 211–15.—Technical Control Units will be introduced into all industries by order of Cabinet Economic Committee. In refineries they will co-operate with laboratories in control of raw chemicals and products as well as help with efficient processing. Such arrangement will result, amongst other things, in raising of standards of production and lend strength to justified complaints. M. S.

Products

Chemistry and Physics

2726. Calculation of the boiling point and dew point of an ideal multicomponent mixture. F. Florin. *Brennstoff-Chem.*, 1952, **33** (9–10), 161–6.—The b.p. and dew point of an ideal multicomponent mixture are determined mathematically by calculation of the points and rises relevant to selected temp. R. T.

2727. Critical solution temperatures in the homologous series of the primary normal alcohols. L. v. Erichsen. *Brennstoff-Chem.*, 1952, **33** (9–10), 166–72. (*From Inst. for anatomy and physiology of domestic animals, Bonn University.*)—Observations on the sol or insol in binary systems precede a discussion of the conception of the crit solution temp in binary systems. Experimental procedure is discussed with explanatory details and a sectional drawing of the apparatus used. Results obtained for the higher primary alcohols do not differ essentially from published data. The val determined for solubility equilibria and crit solution temp of the alcohols investigated from *n*-butanol-1 up to *n*-decanol-1 are reproduced in tables and diagrams. In the discussion of the results, general phenomena in the systems with limited solubility and special characteristics of the *n*-1-alcohols in this respect are examined. These alcohols have an increasing importance in paraffin oxidn for obtaining synthetic fatty acids, and as raw materials for production of surface-active materials and solvents. R. T.

2728. Vapour pressure of the light normal saturated hydrocarbons. R. E. Perry and G. Thodos. *Industr. Engng Chem.*, 1952, **44**, 1649–53.—Vapour pressure data between the triple and critical points were examined by reference to an empirical equation for methane to *n*-dodecane. Data found in the literature were used to obtain coeffs in the equation $\log P = A + \frac{B}{T} + C \log T + \frac{DP}{T^2}$, where P is vapour pressure, T the absolute temp, and A, B, C, and D are the constants.

It is pointed out that similar correlations should exist for the other hydrocarbon groups and the method should be of use in predicting vapour pressure data for distillation problems. E. J. C.

2729. Phase equilibria in hydrocarbon systems. H. H. Reamer, B. H. Sage, and W. N. Lacey. *Industr. Engng Chem.*, 1952, **44** (7), 1671–5.—Phase equilibria are reported for the system methane–*n*-butane–decane at 40° F. E. J. C.

2730. Oxidation characteristics of some diester fluids. C. M. Murphy and H. Ravner. *Industr. Engng Chem.*, 1952, **44**, 1607–12.—Diester-type lubricants find use in turbojet engines, aircraft instruments, etc., where good low temp characteristics, nonvolatility, and high V.I.s are required. Oxidation characteristics and physical properties of nine of these fluids are reported and compared with those of the paraffin eicosane. E. J. C.

2731. Catalysed polymerization of monoalkylethylenes. C. M. Fontana, G. N. Kidder, and R. J. Herold. *Industr. Engng Chem.*, 1952, **44**, 1688–95.—Olefins such as propylene and 1-butene were polymerized using a promoted aluminium bromide catalyst. Products were found to be useful as additives or blending agents for V.I. improvement of lubricating oils. E. J. C.

2732. Sulphur compounds as antioxidants. R. B. Thompson, J. A. Chenicek, and T. Symon. *Industr. Engng Chem.*, 1952, **44**, 1659–62.—Study reported of the antioxidant characteristics of alkylmercapto ketones. Results confirmed that efficiency of such compounds as antioxidants is related to steric configuration. E. J. C.

2733. Patent. Ger.P. 836,801, 13.3.52. E. R. Woodward, assr to Société d'Electro-Chemie. Process for oxidation of pet hydrocarbons with air.
Brennstoff-Chem., 1952, **33** (7–8). R. T.

Analysis and Testing

2734. Free sulphur determination reduced to 15 minutes by new method. O. R. Mitchell. *Refiner*, June 1952, **31** (6), 148.—Free sulphur in oil is determined by contacting with mercury and estimating the mercuric sulphide formed and suspended in the solution with an electrophotometer. The method is claimed to be more accurate and reproducible than the conventional methods. A. R. H.

2735. Detection and determination of small amounts of inflammable hydrocarbons in combustible materials. J. H. Macoun. *Analyst*, 1952, **77**, 381.—The procedure described is based on a method by Hoff for the determination of hydrocarbons in alcohol.

The suspected material is allowed to soak in alcohol overnight. Water is then added and the liquid distilled through a vertical condenser fitted with a straight adapter which can be fitted into the top of a 50-ml burette. Two 20-ml samples are collected in separate burettes, 15 ml of KG_2O_7 solution added to each fraction followed by 2 ml HCl, and the whole shaken and allowed to stand overnight. The volume of hydrocarbon oil is measured, separated, and identified by routine methods. A. G. M.

2736. Pipette for ethylene determination by the bromine method. A. Björkman. *Analyst*, 1952, **77**, 328–9.—A pipette has been designed for the sampling and determination of ethylene. It consists essentially of a 100-ml bulb, containing the gas under slight pressure, which allows the take-off of 20-ml samples of ethylene to be determined by the bromine method.

Two samples of ethylene, one prepared from ethylene dibromide and zinc and the other by dehydration of alcohol, showed contents of 99·1 ± 0·2% and 95·5 ± 0·4% v/v respectively. A. G. M.

2737. Determination of furfural in lubricating oils. W. C. Woelfel, W. D. Good, and C. A. Neilson. *Petrol. Engr*, July 1952, **24** (7), C42–4.—The analysis of traces of furfural in lubricating oils, to control solvent losses, has been carried out by a photometric method which measures the red colour produced by reaction of furfural with aniline acetate. Furfural is washed from the oil sample by sodium bisulphite solution to form the water-soluble addition compound. The interference of excess bisulphite with the colour reaction is eliminated by oxidn with iodine and subsequent reduction of excess iodide by titration with thiosulphate solution. The calibration curve is plotted between optical density and furfural concn, and the results of analysis of known furfural solutions indicate high accuracy coupled with an overall average time for each determination of 15 min. E. K. J.

2738. Volumetric estimation of anthracene in tar oils and tar oil fractions. W. Schmidt. *Brennstoff-Chem.*, 1952, **33** (9–10), 176–9. (*From Chem.-Tech. Inst., Tech. High School, Aachen.*)—A further development of anthracene estimation in crude and conc anthracene applicable to tar oils and tar oil fractions with low anthracene cont is reported. Estimations on standard mixtures showed that the following constituents of fuel oil do not interfere: naphthalene, methylnaphthalene, phenanthrene, carbazole, acridine, pyrene, fluoranthene, acenaphthene, fluorene, and diphenylene oxide. Interfering substances, phenols, and quinoline bases are removed with 10% NaOH solution or 20% H_2SO_4. A 2000-g sample of raw material worked up by dist and solvent extraction is required for the Höchster method, compared with 50 g for the maleic acid anhydride method. Small amounts of anthracene homologues are determined simultaneously. The maleic acid anhydride method is fairly rapid, taking 1·5 hr, the Höchster method takes 2 to 3 days and the Rütgers method 3 to 4 hr. The average error on standard mixtures after applying the correction factor 1·03 is ±0·3%. R. T.

2739. Investigations with gas density balance. Pt 1. The principle and methods of use. I. H. Silberberg and J. J. McKetta, Jr. *Petrol. Engr*, May 1952, **24** (5), C5–8.—The balance and three methods of use for experimental work are described, and the use of air and standard gas is discussed. The balance is shown to be an instrument capable of precise research work into the behaviour of gases at low pressures. The max variation of the mol. wt. of air from the mean has been proved to be 0·05%, and the max deviation of the compressibility factors calculated from the Beattie Bridgeman equation of state is 0·02% of the experimental value, so that air can be used as a standard for gas density balance measurements without loss of accuracy. E. K. J.

2740. Investigations with gas density balance. Pt 2. Compressibility isotherms of methane, ethane, propane, and *n*-butane at low pressures. I. H. Silberberg, P. K. Kuo, and J. J. McKetta, Jr. *Petrol. Engr*, May 1952, **24** (5), C9–20.—The gas density

balance was used to determine compressibility factors of methane, ethane, propane, and *n*-butane at temps between 90° and 200° F. Compressibility isotherms are plotted for the four hydrocarbons at intervals of 30° F between 30° and 210° F as straight lines through the value of the compressibility factor, *z*, at 760 mm and at 0 mm, *i.e.*, $z = 1$. Negligible error is shown to be introduced by the assumption of linearity. Max errors for compressibility factors at 1 atm are quoted as 0·05, 0·08, 0·07, and 0·10% for methane, ethane, propane, and *n*-butane respectively. E. K. J.

2741. Variable head suspended level viscometer. J. W. Young. *Refiner*, June 1952, **31** (6), 145–7.—A new type of viscometer is described which can be used over a range of 200° F. It is designed using the suspended level principle of Ubbelohde, together with a variable lead and requires a sample of less than 3 ml. It has an accuracy better than 1%, and can be applied for the study of non-Newtonian liquids. A. R. H.

2742. New electro-automatic viscometer. Anon. *Brennstoff-Chem.*, 1952, **33** (9–10), 185.—The instrument described and illustrated is put in operation by a push button, and is fully automatic. Errors in stop-watch reading due to the personal factor are obviated. Temp obtained by air immersion heater are maintained to an accuracy of ±0·025° C. R. T.

2743. Micro-capillary viscometer for viscosities up to about 12 poises. Anon. *Bitumen, Teere, Asphalte, Peche*, 1952, **3** (3), 62.—A simple viscometer, readily assembled in any laboratory is described and illustrated. Visc is measured up to 12 poises on one drop only of liq by timing the capillary rise of the liq through each mm of a graduated filter paper strip. Plotted results show a flat curve for low visc and a steep curve for high visc. Tabulated results for linseed stand oil and raw linseed oil with different filter papers show the influence of pore width. Test curves for liq of known visc are plotted on the basis of which the abs visc of test samples can be determined by graphic interpolation. R. T.

2744. Penetration measurement. J. Heinrich. *Bitumen, Teere, Asphalte, Peche*, 1952, **3** (3), 57–9.—Types of penetrometers for measuring hardness or consistency of plastic materials, bitumen, pitch, waxes, fats are discussed and illustrated. A fully automatic instrument, shown diagrammatically and described in detail obviates the unfavourable results obtained with conventional instruments. Special features are projection reading, electromagnetic release and arrest of the drop rod and automatic time limitation. Preparation of test samples is described. Fats and waxes are tested with an ASTM standard fat cone. A graphic representation of dependence of pen on temp between 20° and 35° C shows the consistency of bitumen to vary 1 pen degree per 1° C at *ca* 25° C, beeswax 4 units, and paraffin 10 units. Rise in temp to 35° C shows no increase in val for bitumen, *ca* 10 units per ° C for beeswax and for paraffin *ca* 35 units. R. T.

2745. Engine tests of lubricants. C. Casci. *Riv. Comb.*, 1952, **6**, 248–59.—Describes tests of lubricants carried out with various types of diesel engine at the Koninklijke/Shell laboratory, Delft, with the aim of investigating their performance in service. E. H.

2746. Patents. Ger.P. 839,873, 17.4.52. H. Webster, assr to Odin Clorius A/S, Copenhagen. Vaporization calorimeter.

Ger.P. 841,226, 24.4.52. C. Moreau, assr to Comp. Fabr. Compt. at Mat. d'Usines à Gaz. Pressure gas meter.

Ger.P. 839,142, 10.4.52. S. Brockhaus, assr to Ruhrgas A.G. Device for investigating the interior of gas supply pipes.
Brennstoff-Chem., 14.5.52, **33** (9–10). R. T.

Crude Oil

2747. Refining properties of new crudes. Pt 6. Crude oils from the Julesburg Basin, Colorado, Nebraska and Wyoming. W. J. Wenger and J. S. Ball. *Petrol. Process.*, 1952, **7**, 821–5.—Since 1949 a considerable number of crude oil discoveries have been

made in the Julesburg Basin of Colorado, Nebraska, and Wyoming. Analytical data are presented on thirty-two of these crude oils, as well as data on ten crudes representative of the pre-1949 discoveries. All of the oil discovered in the basin has come from various Cretaceous formations. A field location map of the basin is given. Within the basin two distinct types of crude have been found. The more common is a low-S, brownish-green oil, the second type is a typical black oil. Only one of the discoveries was a black oil of 3·19% S and visc of over 6000 Saybolt. Of the others the majority contained less than 0·1% S. All the oils were wax-bearing. Correlation index curves show the oils to be generally paraffinic in the higher-boiling fractions and naphthenic or aromatic in the lower-boiling fractions. Possible utilizations of the refined fractions are discussed. D. W. F.

Gas

2748. Engineering fundamentals. R. F. Nielsen. *Oil Gas J.*, 28.7.52, **51** (12), 379.—No. 489 in this series deals with combating natural gas hydrates; and illustrates how to determine by calculation whether hydrates may form. G. A. C.

2749. Interchangeability of oil gases or propane–air fuels with natural gases. J. Grumer, M. E. Harris, and H. Schultz. *Industr. Engng Chem.*, 1952, **44**, 1554–9.—Studies of the interchangeability of oil gases or propane–air fuels with natural gases are reported. Graphical data are used to show that if natural gas is to be replaced by either fuel, the adjustment of appliances on the oil gas or propane–air gas is preferable to adjustment on natural gas. For burner adjusted for natural gas, propane–air was more interchangeable than oil gas.

Principles are outlined for determining additives to oil gas which can reduce flash-back or blow-off troubles on natural gas burners. E. J. C.

2750. Flame-stability limits of methane, hydrogen, and carbon monoxide mixtures. J. Grumer and M. E. Harris. *Industr. Engng Chem.*, 1952, **44**, 1547–53.—Method given of plotting flame-stability data for binary fuels consisting of mixtures of H_2, CH_4, and CO, so that the composite flame-stability diagrams for blow-off, and three for flash-back, summarize all the limits for the three binary systems. A method of predicting by calculation burner performance with interchanged fuel gases (*e.g.*, coke oven gas for natural gas) is also given. E. J. C.

2751. Blow-pipe burner for natural gas. W. Dubis. *Nafta*, 1951, **7**, 137–40. (*From work of Polish Petroleum Institute.*)—Blow-pipes are used for glass blowing, precision instruments, etc., and for brass, copper, or silver soldering. So far acetylene, hydrogen, carbon monoxide, and C_3–C_4 gases have been used with oxygen. In the use of natural gas the difficulties were the maintenance of temp at 1000° to 1500° C and the separation of flame. These are due to the fact that natural gas is 98% CH_4, which has high ignition temp (750° C) and low flame velocity (37 cm/sec). From consideration of these and other data a burner was devised to be used when gas pipeline is extended to Warsaw. It can also be used with town gas. M. S.

2752. Calorimetric investigations of natural gas. S. Ocheduszko and I. Zwirski. *Nafta*, 1951, **7**, 133–7; 163–8; 185–90.—Describes in some detail the determination of heat of combustion of natural gas. From previous experience authors knew that this depends also on hydrocarbons present in the atmosphere of a laboratory concerned with such investigations or near oil installations. Other sources of inaccuracy are due to variation of moisture contents, use of tap water for gasmeter calibration, and incomplete combustion, which is very common with CH_4. Final determinations were carried out on three different quantities of primary air using modified Junkers apparatus, Teclu burner, and gas analysis apparatus of high accuracy especially constructed by W. Wisniowski. The analysis of results shows that provided natural gas is burnt at highest flame velocity its cal. val. can be determined with error not greater than ±0·3%. This is considered satisfactory, bearing in mind that this natural gas is CH_{2n+2}, $n = 1{\cdot}0255$, *i.e.*, very nearly all methane. M. S.

Engine Fuels

2753. Sulphurous fuels for diesel engines. Anon. *Motor Ship*, July 1952, **33** (388), 141.—A short report of a process patented by the Bataafsche Petroleum Mij. (B.P. 669,056) for the treatment of sulphurous fuels by the addition of a metal nitrate or carbonate. The presence of sulphur in fuel, although it causes corrosion and gives rise to deposits, nevertheless improves ignition qualities. Certain salts, under the conditions of combustion, form materials which react with the sulphur oxides or sulphur acids to form non-corrosive materials, which are expelled during the exhaust stroke instead of forming deposits. An alkali metal nitrate may form the nitrite or the oxide, which then reacts with sulphur trioxide and water; the water is either formed by the process of combustion or enters the combustion chamber with the intake air. This reaction may occur while the materials are in the gaseous state or on the oil film covering the metallic surfaces of the engine. Engine tests carried out by the B.P.M. are described, and in all of them an improvement in ring wear is reported. U. M.

2754. Auto-ignition properties of certain diesel fuels. J. E. Johnson, J. W. Crellin, and H. W. Carhart. *Industr. Engng Chem.*, 1952, **44**, 1612–18.—A single-cell chamber and a modified three-cell Jentzsch ignition apparatus were used to obtain ignition curves for diesel fuels of varying Cetane No. at atmospheric pressure. Curves plotted show zones of positive ignition, cool flames, and non-ignition in terms of temp and oxygen concentration.

Ignition delay was found to be independent of type of ignition and much more dependent on temp than oxygen concentration. E. J. C.

2755. Trend in motor fuel volatility is still upward. R. C. Alden, E. Aldrich, and H. C. Elder. *Refiner*, July 1952, **31** (7), 115–21. (*Western Petroleum Refiners' Ass., San Antonio, Mar.* 1952.)—An extensive survey shows that the post war increase has been at a slower rate than pre-war. A new way of analysing motor fuel volatility is proposed using as ordinates the sum of the 10 and 30% and of the 70 and 90% evaporated temps. A. R. H.

Lubricants

2756. Take a look at lime base greases through an electron microscope. W. A. Cunningham and M. A. Vela. *Refiner*, June 1952, **31** (6), 110–13. (*American Chem. Soc., Austin, Texas*, 7 Dec. 1951.)—Photo micrographs are presented showing the fibre structure of metallic soaps. No definite correlation was found between the fibre characteristics and the physical properties of the eight greases studied. A. R. H.

2757. Patents. Ger.P. 840,539, 24.4.52. R. Mewes, assr to Dr C. Otto & Co. Process and installation for recovery of utilizable mineral oil residues from bituminous or carbonaceous materials.

Brennstoff-Chem., 14.5.52, **33** (9–10).

Ger.P. 876,536, 13.3.52. H. Engel, assr to Bad. Anilin- & Soda-Fabr. Process for production of lubricant improvers.

Brennstoff-Chem., 7.5.52, **33** (7–8). R. T.

Bitumen, Asphalt, and Tar

2758. Steeping of water-bonded macadam surfaces with very fluid cut-back bitumen. M. Pavaux. *Bitumen, Teere, Asphalte, Peche*, 1952, **3** (3), 63–5. (*From Rev. gén. Routes et Aerodromes*, 1951, **237**, 39.)—Experiments to find a suitable cut-back bitumen for steeping road surfaces and optimum working conditions. The method used since 1947, one application of cut-back bitumen gave adequate pen, *ca* 7 cm, but insufficient cementing. A second application produced the desired results. Laboratory experiments to determine a quant assessment of steeping conditions are described. The experiments were carried out on sample road surfacings compressed to a condition

simulating practice and containing varying quantities of moisture consistent with seasonal weather conditions, using seven different sands. Results are illustrated in photographs and curves and discussed. Road tests were carried out with special attention to the moisture cont at the time of steeping, steeping time, and proportioning of cut-back bitumen in the after-treatment. Practical conclusions drawn are, that it is essential to test the materials used for sp binding and steeping properties. A preliminary steeping with cut-back bitumen 2 kg/m² or usually 2·2 to 2·3 kg/m² is necessary; this is preferred in two steps and in the warm season at *ca* 30° C on a slightly moist surface. Moderate brushing-in is recommended. Further requirements are: sufficient time to allow the bitumen in the preliminary steeping to penetrate; an application of fine chips as late as possible, to protect the bitumen, and an after-treatment one to two months later with a cut-back bitumen of visc 50/100 with an overdosing of 200 to 300 g/m². R. T.

2759. Vaporization and polymerization (ageing) of bitumen binders—formulation of an ageing formula. G. Herion. *Bitumen Teere, Asphalte, Peche*, 1952, **2** (3), 36–42. (*Thesis on work from Mar.* 1950 *to Apr.* 1951 *in testing station of Soc. for tar road construction on bitumen binders.*)—An investigation is described of nine binders, tar, tar-bitumen, and bitumen of widely different properties, to establish the influence of vaporization and polymerization on the raising of visc and change of properties. Visc–temp relationships are given in a chart. The magnitude of stiffening as a function of temp was obtained by exposing thin films of binder on glass plates for 1 day, 3 days, and 1, 2, 3, 4, 5, 6, 7, 8, and 12 weeks at room temp (*ca* 22° C) and 40° C and determining the wt to a degree of accuracy of 1/100 g. The results presented in graphs were interpreted by comparison with the fractional dist tabulation. These val represent total stiffening. Since this is not a linear function of temp, the hardening properties were investigated at *ca* 10° C above the average mixing temp. (Heating test.) Combination of these results with those of the ageing test gives a conclusive basis for evaluation of the binders. For a ready evaluation of the ageing and heating tests the results are combined conveniently in formulæ. The arrangement and execution of ageing experiments are described in which the soft. pt., R. and B. of the binders is taken into consideration in the undisturbed condition, and after 28 days storage at *ca* 22° and 40° C. The results of the ageing investigations by estimation of the total stiffening dependent on temp and the proportion of the vaporization and polymerization of the total stiffening independent of temp are discussed and ageing and heating formulæ developed. R. T.

2760. Some applications of asphalt to hydraulic works. H. A. Ferguson. *Ingenieur*, 1.8.52, **64** (31), B123–30.—Sand–bitumen mixtures need a min of 5% bitumen to ensure complete enrobing of the sand particles, but for hydraulic applications, bitumen contents of 15 to 20% are considered necessary. Coatings of seashore embankments require different properties and methods of application for the submerged, exposed, and tidal zones of the embankment surface. Destruction of the coating by vegetation and animal pests and means to avoid it are dealt with. Seventeen photographs illustrating different applications and defects are discussed extensively. G. F. T. C.

2761. Glance into the colloidal system of coal tar pitch. H. Mallison. *Brennstoff-Chem.*, 1952, **33** (9–10), 172–6.—Investigations on tar dist to remove H_2O and low-boiling constituents are reported. The complex colloidal nature of tar and pitch and their systematic distribution are shown by dist and the use of selective solvents in association with the use of the microscope. Supporting tables, photomicrographs, and charts are presented. R. T.

2762. Patent. Ital.P. 443,199, 10.12.48. G. Ballabio, assr to Azienda Nazionale Idrogenazione Combustibili. Emulsifier for bitumen emulsions. The emulsifier is produced by oxidizing paraffin to sap. No. 230 and acid No. 100 and sulphonating at 45° C with 20% fuming H_2SO_4. The emulsions are produced after adding 0·5 to 1·5% of this product to bitumen by emulsifying with 80° hot water, which must contain 35 g calcined soda per kg bitumen.

Bitumen, Teere, Asphalte, Peche, 1952, **3** (3). R. T.

Special Hydrocarbon Products

2763. Aromatics from petroleum. Anon. *Petrol. Process.*, 1952, **7**, 839–44.—Reviews are given of four papers presented at the Mid-Yr mtng API Refining Divn, San Francisco, 14 May, during the session on production and recovery of aromatics.

Platforming and udex extraction. From " Production of high-purity aromatics from chemicals," by D. Read. The overall economics of producing aromatics by the combination of these two processes are discussed and illustrated with pilot plant data for the two operations.

Houdriforming for aromatics. From " Houdriforming at low pressure," by J. C. Dart, A. G. Oblad, and J. W. Schall. High yields of aromatics were obtained by the relatively low pressure Houdriforming of a typical motor naphtha containing a total of 41% vol naphthenes. Aromatization of paraffins is said to occur under slightly more severe conditions.

Recovery by extractive distillation. From " Shell extractive distillation process for recovery of high purity aromatics," by C. L. Dunn and G. E. Liedholm. For the production of nitration grade aromatics a commercial plant must be designed for 99·5% purity. A process capable of this is extractive distillation. One Shell plant designed for toluene recovery has also been used for extraction of benzene and mixed xylenes using mixed cresylic acids as solvent.

Recovery by silica gel adsorption. From " The Arosorb process in refinery operations," by W. H. Davis, J. I. Harper, and E. R. Weatherly. Summarized data are presented on aromatic products from processing several kinds of charge stocks. Operating costs for Arosorb processing of catalytic reformate are tabulated. D. W. F.

Derived Chemical Products

2764. Petroleum-chemicals reviewed. R. F. Goldstein. *Petrol. Times*, 25.7.52, **56**, 625.—Author continues the periodical reviews of the petroleum-chemical industry that have been a notable feature of *Petrol. Times* in recent years. As foreshadowed in previous articles, the world-wide demand for chemicals from petroleum continues to increase, and the outstanding trends in Europe, Canada, and the U.S.A. in synthetic alcohols, synthetic rubbers, synthetic fibres, and in agricultural chemicals are now discussed.

The main applications of gases from steam-cracker units are illustrated by reference to the Wilton plant in the U.K., while the probable consequences of increased availability of gases from catalytic cracking units are considered. Mention is made also of recent developments in the U.S.A. concerning synthetic rubbers. Output of GR–S is now reported to approach 850,000 tons p.a., half of which is " cold rubber." The newer developments in this field include " oil-extended rubber "—GR–S incorporating some 25% by weight of cheap petroleum oils and a synthetic rubber made not in a water emulsion but in a hydrocarbon solution. The butadiene required for American GR–S is now derived entirely from petroleum, and still further expansions are projected. Manufacture of butyl rubber, too, is intended to be increased to 115,000 tons p.a.

An indication of the scale on which petroleum chemicals are used in agriculture is provided by the great expansion of facilities for ammonia synthesis from natural gas, by the proposed increase in D.D.T. production in the U.S.A. to 70,000 tons p.a. by 1955, and the fact that the consumption of sulphur for fertilizers and pest control purposes in America exceeds 20% of the total consumption of sulphur in that country. There are plans to produce from 20,000 to 25,000 tons p.a. of sulphur from refinery gases in the U.K.

Developments in synthetic fibres which are or may be derived from petroleum sources are reviewed, with particular reference to nylon and terylene. Although it is difficult to foresee future prospects in the textile industry, an increased demand for synthetic fibres seems assured. Detailed breakdowns, in tabular form, are included of the principal production projects for synthetic ammonia, synthetic fibres, and the application of polyalcohols. Consideration of the latter suggests probable shortage of glycerine, which is attributable to increased consumption of synthetic detergents and a

consequent reduction in by-product glycerine from soap manufacture. Developments in alkyd resins are largely responsible for the projected expansion of pentaerythritol, which in the U.S.A. may rise from 40,000,000 lb in 1951 to 60,000,000 lb by 1955.
J. H. P.

2765. Conversion of natural gas into chemical products. E. L. Krugers Dagneaux. *Chem. Weekbl.*, 16.8.52, **48** (33), 589–96.—Natural gas has been found in several places in Holland. At the moment the total production is estimated at a max of 200,000 cu. m/day for ten years. The composition, density, and gross cal. val. of the gas from the wells in Tubbergen, Gramsbergen, and Wanneperveen are given. It seems very attractive to convert this gas into chemical products. An outline is given of the markets that are within possible economic reach of Holland. The author states that the conversion into acetylene, channel carbon black, and Fischer–Tropsch synthesis gas is not attractive for Holland. In the future the conversion into ammonia and cyanic acid may be of importance for the manufacture of ammonium sulphate and plastics. The manufacture of methanol, formaldehyde, and carbon bisulphide is very important, because these materials are indispensable for the existing Dutch industries of plastics and synthetic fibres and are not at present produced in Holland. Moreover, it will then also be possible to make pentaerythritol and hexamethylene tetramine. By means of chlorination, natural gas may be converted into various solvents, refrigerants, dispersing and extinguishing agents, and intermediates.
M. M. J. J. S.

2766. Will coal supply all aromatics? V. B. Guthrie. *Petrol. Process.*, 1952, **7**, 833–7.—To produce aromatic compounds as direct products from coal, instead of as by-products of petroleum refining, Carbide and Carbon Chemical Co. have developed a high pressure coal hydrogenation process to the stage of a very large pilot plant. The plant, with a capacity of 3000 tons/day of coal, occupies a 20-acre site and is complete in itself. A brief description with flow diagram is given of the process and the four major sections of equipment. A pulverized coal–oil paste is reacted with hydrogen at temp of 840° to 1000° F and pressures up to 6000 p.s.i. to form a predominantly liquid product which proceeds continuously to a " hot " separator. The liquid stream from this contains ash and unreacted coal and an oil which is recycled for making the coal paste. The vapour stream is condensed in a " cold " separator, and it is this liquid stream that is passed to the chemical separation unit. A summary is given of the major products obtained but no operating data. D. W. F.

2767. Coal removes phenols from wastes. G. Gutzeit. *Petrol. Process.*, 1952, **7**, 828–32.—Hydrophobic solids, such as bituminous coal, have a strong tendency to adsorb on their surface polar–non-polar compounds like phenols, or creosote, mercaptans, fatty acids, and similar compounds. This fact is utilized to treat tank car cleaning wastes containing up to 500 p.p.m. phenolic compounds in a plant built by General American Transportation Corpn. The coal is finely ground and suspended in the waste after the pH has been adjusted to the proper value by adding acid, and sufficient contact time allowed. Flotation is used to separate the coal, which is then filtered, dried, and used as a fuel. The plant described reduces the phenol content to 50 p.p.m., after which the waste is treated by biological oxidation. A flow diagram of the process and treatment results on the plant are included. D. W. F.

2768. Patents. Ger.P. 839,348, 10.4.52. O. Grosskinsky, G. Huck, and J. Karwell, assrs to Kohlentechnik G.m.b.H. Process for obtaining an essentially C product with high chem and physical reactivity from coal.

Ger.P. 840,989, 24.4.52. P. Schmalfeld, assr to Metallges A.G. Process and arrangement for production of active C by activation of carbonaceous materials.

Ger.P. 839,791, 17.4.52. L. Riedhammer, Nüremberg. Process for utilization of petroleum small coke.
Brennstoff-Chem., 14.5.52, **33** (9–10). R. T.

Miscellaneous Products

2769. Kinetics of the fatty acid esterification of poly-alcohols. W. Rubin. *J. Oil Col. Chem. Assoc.*, 1952, **35**, 418.—A study of the rate of fatty acid esterification of poly-alcoholic resins was made. The kinetics of the reaction are shown to be of the second order. The relationship between activation energy and collision frequency is discussed. Various catalysts accelerated the reaction, and a reaction mechanism is suggested. The possible practical application of the results is outlined. D. K.

2770. Reaction between styrene and drying oils. A critical survey of published papers. S. Kut. *Paint Technol.*, Apr. 1952, **17** (196), 149; May 1952, **17** (197), 199.—Pt 2. The presence of polystyrene in the reaction between styrene and drying oils is discussed with particular reference to the work of Schroeder and Terril, and Dyer and Maxwell. The copolymerization of drying oils is considered, and various mechanisms are suggested. Hewitt and Armitage and other workers favour a chain mechanism. A Diels–Alder type condensation is not thought to occur during the reaction. Further work discarding the ionic mechanism is also reported. Uncertain and incomplete results are the subject of much of the work discussed.

Pt 3. A critical examination is made of the recent work of Petit and Fournier. They analysed a commercial styrenated linseed oil, isolated pure, acid free polystyrene. From results obtained they concluded that styrenated oils cannot be called true polymers. D. K.

2771. Phosphate coatings in cold forming. R. N. Warring. *Mech. World*, May 1952, **131** (3394), 202.—Phosphate surface treatment of many metals converts the metallic surface into a non-metallic skin which has certain lubrication properties, but which is also an ideal base for the application of special "dry" lubricants. These surface coatings have enabled cold working technique to be considerably extended. T. T.

Corrosion

2772. Work of the Protective Coatings (Corrosion) Sub-Committee. F. Fancutt and J. C. Hudson. *J. Oil Col. Chem. Assoc.*, 1952, **35**, 396.—Investigations carried out on protective coatings for iron and steel structures during the last twenty years are surveyed. Research has shown the importance of correct surface preparation and the value of using inhibitive priming paints. Many types of paints were tested, including tar pitch and bitumen-based paints. Studies are in progresss on anti-corrosive paints for land and marine use. Basic data have been obtained for the performance of aluminium, cadmium, lead, tin, and zinc coatings. The durability of zinc coatings was found to be approx proportional to their thickness. Sprayed aluminium proved to be an effective coating. Lead coatings have given good results in industrial atmospheres, where they become coated with a protective sulphate film. D. K.

2773. Corrosion control. Anon. *Oil Gas J.*, 14.7.52, **51** (10), 141.—The preparation of tanks and installation of reinforced concrete bottoms is outlined. A figure shows dimensions for concrete and reinforcing layouts. G. A. C.

2774. Corrosion control. Anon. *Oil Gas J.*, 21.7.52, **51** (11), 107.—Deals with preparation of tanks for application of paint as a protective coating. Steel surfaces must be cleaned either by wire brushing, sand-blasting, pickling, or flame-priming. G. A. C.

2775. How to protect storage tanks. Anon. *Oil Gas J.*, 4.8.52, **51** (13), 109.—Pt 8 discusses three basic types of primers. Repeated tests have shown red lead to be superior to any other type. G. A. C.

2776. Mitigation of corrosion within cargo compartments aboard a T-2 tanker. G. D. Harden. *Proc. 3rd World Petrol. Congr.*, 1951, **8**, 79–85. A system developed by Shell Oil Co. for mitigation of corrosion in tanker compartments using magnesium anodes and chemical inhibition. E. J. C.

2777. Corrosion protection of underground pipes and soil survey. A. J. Maurin. *Proc. 3rd World Petrol. Congr.*, 1951, **8**, 50–70. (In French.)—Discusses soil survey of pipeline routes with a view to applying cathodic protection, and illustrates the corrosive effect of various soils by reference to charts. Typical cathodic protection systems are illustrated and discussed. The report is based on experience gathered with all types of pipelines over a period of years. E. J. C.

2778. Safety and economy in the protection of underground steel pipes. O. L. Bihet and H. Goldstein. *Proc. 3rd World Petrol. Congr.*, 1951, **8**, 71–6. (In French.)—Experience gained in protection of buried pipelines in Belgium. Reported that most satisfactory protection obtained using a blown asphalt bitumen to which talcum may be added, and reinforced with bitumen impregnated with glass wrapping, which gives a very good coating. This coating is supplemented with cathodic protection. E. J. C.

2779. Surface corrosion of heat-resisting materials under the action of bunker oil ashes containing sodium, sulphur, and vanadium. F. Gallman, J. Friedli, and W. Epprecht. *Proc. 3rd World Petrol. Congr.*, 1951, **8**, 32–43.—Describes the initial part of a detailed programme designed to study the behaviour of heat-resisting metals under the action of oils containing sodium, vanadium, and sulphur. Various plates of Cr–Ni steels were heated to 650° C for 1000 hr with and without oil ash on the surface. For the alloys examined, the presence of oil ash particularly showed the difference of susceptibility of the samples to scaling Although scaling was considerable in some cases, no damaging effect to the metal beneath the scale was noticed. Report is illustrated with reference to microscopic photographs and X-ray photographs. E. J. C.

2780. Rust inhibited distillate fuels. F. M. Watkins. *Proc. 3rd World Petrol. Congr.*, 1951, **8**, 86–95.—Discusses corrosion problems associated with handling and storing petroleum products, and describes tests carried out using a rust inhibitor which can be added to distillate fuels. E. J. C.

2781. Vinyl plastic coatings. Anon. *World Petrol.*, 1952, **23** (6), 42–5.—Vinyl resin coatings applied to drilling and well-head equipment, tankage, pipelines, interior decoration in tropical regions, have shown spectacular savings in maintenance and replacement as a result of their corrosion-resistant and anti-fouling properties. Numerous examples of their wide use are quoted and experiments described. E. B.

2782. Have you tried aluminium in your refinery? E. D. Verink, Jr. *Refiner*, July 1952, **31** (7), 141–4.—The use of aluminium in the petroleum industry is discussed. It has proved resistant to hydrogen sulphide, carbon dioxide, ammonia, cooling waters, and furfural. A. R. H.

2783. Chemical reconditioning of rusted metal surfaces. Anon. *Mech. World*, May 1952, **131** (3394), 216.—The renovation by the Jenolite process of service vehicles taken out of storage is described. There are four stages in the process : degreasing and paint stripping, water rinsing, scale removal, and a second water rinsing. The metal emerges free from rust, proofed against further rust, and keyed for paint. T. T.

2784. Patent. Swiss P. 262,556, 1.10.49. B. O. Wonesch. Coating for fodder silos. As protectives against formic acid, salts and sulphonic acids, tar or bitumen lacquer, also water glass, emulsion paints containing rubber latex are recommended. In presence of these corrosives the latex coagulates and covers the walls uniformly with a resistant film.
Bitumen, Teere, Asphalte, Peche, 1952, **3** (3). R. T.

Engines and Automotive Equipment

2785. Ash and the coal-fired gas turbine. T. F. Hurley. *J. Inst. Fuel*, July 1952, **25** (144), 185.—The main difficulty to overcome with coal-fired gas turbines is the presence of ash in the fuel ; this is more pronounced in the open-cycle turbine than in the

closed-cycle type. In the closed-cycle ash problems resemble those of the steam boiler, the only basic difference being the higher temp of the tubes of the " air-boiler " of the turbine. In the open-cycle it appears that cleaning of gases by very efficient types of multicyclone may be sufficient. Even so, the ash may affect greatly the method of combustion selected and the design of the combustion chamber. " Dry " combustion chambers, ash carried out as finely divided particles, and " wet " combustion chambers, ash removed as molten slag, are being investigated as is also two-stage combustion, where fuel is converted to producer gas, which is cleaned before being burnt. D. K.

2786. Gas turbine locomotive. Anon. *Petrol. Times*, 22.8.52, **56**, 694.—Some technical details, extracted from the current issue of the *Metropolitan-Vickers Gazette*, are given of the gas turbine electric locomotive which has been in regular service in the Western Region of British Railways. G. A. C.

2787. The Proteus 705. Anon. *Flight*, 1952, **61** (2263), 687–92.—The design of the Bristol Proteus 705 (Series 3) turbo-prop engine is described in detail. Embodying advances made with the earlier versions of the Proteus, together with a number of detail design refinements, this reverse-flow unit has eight combustion chambers housing flame tubes of riveted construction, a twelve-stage axial compressor to which the final centrifugal stage is bolted, and two two-stage turbines. Article is illustrated by a drawing of the complete unit and photographs and diagrams of components, whilst designed performance curves show a maximum shaft h.p. figure of 3300 (at sea-level), plus 1200 lb jet thrust. N. L. A.

2788. A modified Farnboro electric indicator. W. J. R. Roach and J. G. G. Hempson. *Engineer*, 1952, **194**, 7–9, 57–61.—Apparatus developed to determine mechanical efficiency of large slow-speed marine oil engines. No previous instrument sufficiently accurate for determination of i.m.e.p. at these low speeds. Dobbie–McInnes Farnboro indicator suitable for high-speed engines, but at low speeds disk-valve unit in pick-up unsuitable. New pick-up unit designed incorporating low modulus, carefully heat-treated metal diaphragm, sensitive to 0·05 p.s.i. differential pressure and low rates of pressure change, yet capable of withstanding 1300 p.s.i. max pressure. Nitrogen gas at known pressure from bottle at 1850 p.s.i.g. applied to top of diaphragm, when pressure in engine cyl, which communicates to underside of diaphragm, rises to nitrogen pressure, diaphragm flexes and completes circuit. Electronic amplification of current finally indicated by spark perforation of paper on revolving drum. Accurate indication of dead centres essential, max permissible error of $\pm 0{\cdot}1^\circ$ crank angle limits error in mean pressure measurement to $\pm 0{\cdot}5\%$, corresponding to linear measurement of 0·004 inches on periphery of recording drum. Typical indicator diagrams at 100 and 800 r.p.m. given, with diagrams and photographs of equipment, and analysis of possible errors. A. C.

2789. Aeration and foaming in lubricating oil systems. R. Tourret and N. White. *Aircr. Engng*, 1952, **24** (279), 122–30.—A survey of the existing state of knowledge regarding oil aeration and foaming, with particular reference to the aero-engine. The troubles that can be caused by oil aeration and foaming are summarized. The behaviour of air and gases in a liquid is treated theoretically, and the mechanism of foam formation is described. The three stages into which the mechanism of foam decay appears to be divided are outlined, as well as the influence of various factors (visc, surface tension, vapour pressure, temp, bubble size, etc.) affecting foam decay. The performance of each component in a conventional piston-engine lubrication system in relation to oil aeration and frothing is examined. In a short section dealing with lubricant properties affecting foaming, attention is drawn to the influence of contamination with gasoline, water, or gasket sealing compounds on the foaming characteristics of an oil. Methods of overcoming aeration and foaming in aero-engines are discussed in the final section of the article, both mechanical design arrangements and the use of anti-foam additives being considered. N. L. A.

Safety Precautions

2790. Modern fire protection equipment for refineries and storage. H. E. Bedford. *Proc. 3rd World Petrol. Congr.*, 1951, **8**, 236–41.—Outlines the development of fire protection over thirty years and describes newer techniques, including the dry chemical extinguisher, water-fog and foam, and modern equipment. E. J. C.

2791. Fire fighting in petroleum industry. S. Rachfal. *Nafta*, 1951, **7**, 190–201.—Describes possible causes of petroleum fires and points out that an oil moving through pipeline at 2·5 m/sec may develop 3000 V potential. Detailed analysis is given of nature of fire and explosive limits for petroleum products, conventional methods of extinguishing such fires, *e.g.*, fine spray of water, bicarbonate of soda solution, CCl_4, CH_3Br, CO_2, and foams. Mechanical and chemical foams are the subject of legislation defining their properties.

Pt 2 deals with different types of extinguishers, manual and transportable on wheels, and Pt 3 with such large extinguishers as may fit into petroleum tanks, their principles of construction, and sizes stipulated by insurance companies.

Pt 4 describes ways of putting out big petroleum fires, but does not touch on well fires. M. S.

2792. Non-sparking tools. L. Bernhardt. *Engineer*, 1952, **194**, 6–7.—Main reason for ferrous metals being prone to sparking is ease with which iron oxide is formed in air when iron particles detached on impact. Particles first preheated by energy required to tear them from parent metal. Oxidn which occurs is then markedly exothermic (1600 cal/gm), raising particles to incandescence. Heat of formation of copper oxide only 314 cal/gm. Safety tools with cutting edges usually made from beryllium copper (*ca* 2% beryllium), on account of greater hardness and strength than other non-sparking alloys. For less severe duties such as hammers, spanners, etc., aluminium bronze satisfactory and less expensive than beryllium copper. More experimental work required to assess relative sparking properties of various metals by impact as distinct from friction. In order to raise temp of combustible vapour to ignition point, sparks must reach even higher temp; their heat content above ignition temp must be sufficient to transfer necessary amount of heat to min vol of mixture; and therefore, because of cooling effect due to convection, flying sparks less dangerous than those whose path is obstructed by thermal insulator. A. C.

Miscellaneous

2793. Our inexhaustible resources. E. Holman. *Bull. Amer. Ass. Petrol. Geol.*, 1952, **36** (7), 1323.—"Geologists often refer to the materials they seek as 'wasting,' or 'exhaustible' resources, mainly through the fear that they are going to run out of one or other"—this viewpoint was expressed by the author (not himself a geologist) at a joint annual meeting of U.S. geologists, palæontologists, mineralogists, and exploration geophysicists. In his address he endeavoured to point out that this was a partial viewpoint.

Men from earliest times to the present day have used minerals drawn from the earth. This concept of unlimited raw materials does not mean that progress is simple; these raw materials require the human mind to activate them and this can only be done under free conditions. So many parts of the world have conditions that are not conducive to progress.

From the earliest metal to plastics, natural resources and Man's knowledge have benefited the world, but Man must know how to use his discoveries to the full, and thereby produce another step in the pattern of material progress, and thus expand the natural resources open to him. E. N. T.

2794. World production stays close to 12,000,000 barrels daily total. Anon. *World Petrol.*, 1952, **23** (7), 32–5.—Estimated crude production for first half of 1952 was 11,866,400 b.d., <2% increase on same period for 1951. Individual countries, production figures, and current activity are discussed. E. B.

2795. 1951 oil profits increase 20 per cent over 1950. Anon. *World Petrol.*, 1952, **23** (6), 46–9.—Rise in profits reflected American part in replacing Iranian crude as well as continued demands of Korean war and European recovery. Domestic and foreign demand for gasoline continues to rise, and expansion in all phases of the industry is being anticipated. A four years' financial review of thirty U.S. companies and two foreign affiliates is tabulated. E. B.

2796. Development lines (routes) of the (Polish) petroleum industry. J. Drzewiecki. *Nafta*, 1951, **7**, 182–4.—A brief summary of development since before the war, through German occupation and first three-year plan, leads into analysis of present-day state of industry. Amongst difficulties are noted lack of co-ordination and shortage of funds.

Future plans include improvements at all stages, as well as realization of the aims of six-year plan. M. S.

2797. Nation has 24 processing plants building, planned. R. B. Tuttle. *Oil Gas J.*, 28.7.52, **51** (12), 252.—Survey of natural gasoline plant projects in the U.S.A. shows an estimated capacity of approx 27 million g.p.d. G. A. C.

2798. Refining capacity nearing 7·5 million barrels. R. B. Tuttle. *Oil Gas J.*, 28.7.52, **51** (12), 244.—Survey of active crude oil refining projects in the U.S.A. shows an estimated step-up by more than 150,000 b.d. by end of 1952. G. A. C.

2799. Value of United Kingdom oil imports. Anon. *Petrol. Times*, 22.8.52, **56**, 715.—Report shows definite signs of recession of U.K. imports in the half-year Jan./June 1952. Tables show c.i.f. values of liquid and solid petroleum imports and of crude oils and refined products from individual consignors. G. A. C.

2800. United Kingdom petroleum trade in June and the first half of 1952. Anon. *Petrol. Times*, 8.8.52, **56**, 656.—Figures are given for imports and exports, and a summary provided. Lowest motor spirit imports since war ended are revealed. G. A. C.

2801. Petroleum industry and the D.S.I.R. Anon. *Petrol. Times*, 22.8.52, **56**, 707.—Points from the 1950–51 report of the Advisory Council to the British Department of Scientific and Industrial Research include provision of standard hydrocarbons and carbon isotopes, fire research, hydrocarbon synthesis, gas turbines, lubrication, wear and corrosion, standard engine tests for lubricants, bituminous surfacing, and hydromechanics research. G. A. C.

2802. Impressive volume of tankers under construction. Anon. *Petrol. Times*, 22.8.52, **56**, 712.—The mid-1952 position of the world's tanker fleets is reviewed, and shows great increase in new contracts, rise of independent owners, and rise of average size of ship. G. A. C.

2803. International Court's decision on jurisdiction in Persian oil dispute. J. E. S. Fawcett. *Petrol. Times*, 8.8.52, **56**, 657.—The serious implications of the decision are reviewed, the judgment of the Court upon the issue of jurisdiction and the view which the majority of judges took of the concession agreement of 1933 being dealt with. G. A. C.

2804. Ash and atmospheric pollution. A. Fitton. *J. Inst. Fuel*, 1952, **25**, 178.—The source and amount of atmospheric pollution due to ash and associated grits is indicated. Methods of measuring the concentration of fly-ash in flue gas and of particle size determination are outlined. Means by which atmospheric pollution can be reduced are discussed. Settling chambers, centrifugal separators, electrostatic precipitators, ultrasonic dust extractors, and two of the film-type washers are particularly noted.

The size, nature, and quantity of ash emitted varies with the type of coal, type of combustion unit, and whether or not a dust-extractor plant is fitted. D. K.

2805. Smog—its status today. F. Breese. *Petrol. Process.*, 1952, **7**, 801–5.—The present-day smog problem over large cities is brought to light by particular reference to the climatic conditions in the Los Angeles Basin. Atmospheric conditions are such that for the majority of the year an inversion layer exists over the basin at a height varying from 500 to 2000 ft above sea-level. Surrounding mountains form a boundary around the basin, trapping polluted air rising from the city which cannot break through the inversion layer. A recent theory suggests that the pollution of air is due principally to the atmospheric oxidation of unsaturated hydrocarbons. Arguments for and against this theory are presented, together with the part being played by the oil industry to alleviate the problem. Responsibility for a considerable part of the nuisance is placed on the exhausts from the automobiles in Los Angeles as well as on cracked gases and vapours escaping from refineries and storage tanks. D. W. F.

2806. Waste and by-products from refineries as chemical raw materials. A. Wachal. *Nafta*, 1951, **7**, 202–11.—In order to cut down losses from petroleum refining its by-products must be utilized. The difficulty lies in the great variety of compounds present in crudes. Two main groups of waste materials can be distinguished: (*a*) chemical refining residues, and (*b*) thermal refining (cracking) residues.

The latter group consist of very valuable gases. Author deals first with acid-refining waste and points out two methods of recovery of H_2SO_4. Then follows a table of various sulphonic acids and their origin according to Sperling. Recovery preceded by neutralization is considered wasteful.

The purely organic material of very high unsaturation value is considered as a very valuable potential source of hydrocarbons whose complexity will one day be overcome as has that of coal tar.

Alkaline residues are mostly Na salts of various sulphonic or naphthenic acids or Na_2SO_4. They can be salted out. Sulphonic and naphthenic acids and their derivatives can be utilized in metallurgy as floating agents, anti-corrosive agents, in spinning as de-oiling and cleaning compounds, wetting agents for dyeing, de-inking agents in paper industry, emulsifying agents, saponifying agents, plasticizers, insecticides, water-proofing agents, corrosion inhibitors, and additives to high pressure oils.

Solvent refining gives extracts of high aromatic contents which can be used as plasticizers and petrolatum, which on cracking forms unsaturateds.

Cracking gases and their uses are given in tabular form, and Polish, German, and Russian books are quoted. M. S.

2807. Hints for burning acidic fuels. Anon. *Petrol. Process.*, 1952, **7**, 806–7. (Based upon "Steam and power plant economy and capability at Louisiana station," by R. J. Robertson and W. B. Gurney, Petroleum Divn ASME., Sept. 25–28, 1950; and further information.)—Experience with the problem of burning acid sludges, acid tars, and high-sulphur refinery gases has led to the following conclusions in connexion with air pre-heaters: (*a*) Air pre-heaters are essential to minimize overall corrosion; (*b*) Preheater corrosion is prevented by maintaining a min metal temp of 300° F; (*c*) For flue gases containing more than 17% water metal temp must be greater than 200° F. Lower temp permissible for lower moisture; (*d*) Lime coating protects preheater from SO_3. Suggestions on the handling of the liquid fuels are also given. D. W. F.

2808. Catalysts for the United Kingdom. V. S. Swaminathan. *Petrol. Engr*, July 1952, **24** (7), C20–1.—The plant for manufacture of microspheroidal alumina–silica cracking catalyst at Warrington, Lancs pumps a mulled alumina–silica slurry at 5000 p.s.i.g. to a cone-shaped spray drier 22 ft dia and 50 ft high. The dried catalyst is washed on a horizontal vacuum filter and redried in a direct-fired rotary dryer. E. K. J.

2809. Organization of the chemical society at the German coal mining administration. Exchange of experience of the coal mining chemists. Anon. *Brennstoff-Chem.*, 1952, **33** (7–8), 101–60. (*Lecture on* 27.3.52 *in Essen.*)—A review of ten papers by various authors under the following headings: Presentation of problems and organization of the chemical society; Laboratory problems for the control of coke oven operations; Control of the saturation operation; Experiences with refractory structural materials

in coke oven and steam boiler construction, coking capacity determinations and their practical importance; Methodical improvements in the sulphur estimation process; Rust protection in mining operations; Protective coatings, their composition and investigation; Testing of oils used in the works; Investigation of mine fire gases.
R. T.

2810. Fuel, heat and power auditing. L. Clegg and J. P. Walters. *J. Inst. Fuel*, 1952, **25**, 136.—The work is discussed of the mobile testing units of the Fuel Efficiency Branch of the Ministry of Fuel and Power. A description is given of the unit, its design and equipment, and its method of operation. Details of an industrial process, which has been surveyed, are included. D. K.

2811. How to prepare preliminary cost evaluation reports. P. W. Sherwood. *Refiner*, 1952, **31** (6), 126–30.—A detailed description of a form of cost evaluation report with examples is presented. A. R. H.

2812. Bulletin supplement. Main Petroleum Institute, 1951, **1** (4). *Nafta*, 1951, **7**, 13–16.—Deals with a newly designed electric heater to be placed at the bottom of the well to help to recover the paraffin wax and to lower visc of fluids. It is designed for 8 kW, and will raise the temp of the well bottom from 20° to 65° C in 1 hr.

Describes a transportable gas oven for sharpening steel bits up to 12-inches dia. It is nearly twice as economical as a brick oven and uses gas at 300 mm Hg, but different burners are available for other pressures.

Contains short notices on neutron logging of two well-known boreholes, on γ-radiation logging, which showed a characteristic fall in intensity when coal deposits were approached; on proceedings of Gas Subcommittee of Main Petrol Inst., which discussed stripping methods and resolved that more crude should be processed and stripping efficiency, especially for C_3, should be raised; and on activity of Petroleum Technology Establishment and its sections. M. S.

2813. Bulletin supplement. Main Petroleum Institute, 1951, **1** (3). *Nafta*, 1951, **7**, 9–12.—(1) Includes paper by W. Paraszczak on "Experimental drilling with sliding bit type IN." A bit one-seventh normal size was used together with rope and connexions to scale on an artificial drill hole made of 150-mm steel pipe filled with mud and sandstone.

The hole exceeded the size of the bit by 35 to 76%, depending on formation.

Theoretical formula by Zuber ($a = D_0 - D_s = D_b - 2x - D_s$; D_0 = dia of hole; D_s = O.D. of sleeve; x = amplitude of slide; D_b = dia of bit) gives an average value exceeded in drilling through soft formations. Another model was used later and gave similar results in artificial and real formations. Previous observations were confirmed and it has also been discovered that frequent sharpening and "true-ing" are necessary, but a sliding bit gives a very straight hole.

(2) Gives reports of the electronic section of Geoanalitical Establishment on radioactivity, reports of Petroleum Technology Establishment on wetting agents, solvent refining, and laboratory methods, report of Scientific Documentation Section on publications and new library.

(3) Experiments on exploitation, exclusion of formation water during drilling, and hydrocarbon consuming bacteria are briefly described. M. S.

2814. Science and technique in Soviet Union (Monthly Review). Anon. *Nafta*, 1951, **7**, 148–50; 176–9.—First review deals with the following points: (1) works safety in Soviet petroleum industry is achieved by teaching some of the crew all the details of processes employed, lectures and posters campaign, and providing all equipment with guards; (2) high-pressure pump gland packing made of fitting semicircular lead rings with holes for graphite grease interleaved with leather rings. Diagram provided; (3) details of transportable derricks; (4) official figures of progress in five-year plan; (5) progress in Roumania. In second review history is traced of Russian oilfields from

1812 to present day. Baku was the area of greatest development, and its crudes dictated the way to refinery development. New oil-bearing sands were discovered between Volga and Ural so rich that they were known as Second Baku, but S content was approx 1·5%. A 10,000-ton/day refinery is being built. Modern scientific methods of refining give final products of first quality. Polish industry benefits from progress in U.S.S.R., and imports of equipment from that country takes place of American imports. Metallurgical and engineering progress facilitates deeper drilling.

Inventions like turbine drilling, "electro-drill," directional drilling, portable rigs, but primarily time and motion analysis of drilling increase efficiency.

An account of progress during the five-year plan follows. M. S.

BOOK REVIEWS

Rotary Drilling Handbook. 5th Edn. J. E. Brantly. London : Palmer Publications, 1952. Pp. 702. 70*s*.

This fifth edition of J. E. Brantly's handbook has been largely rewritten to cover the advances which have taken place in both the practices and equipment used in rotary drilling since 1948, when the fourth edition was published. The writer has found it possible to maintain the work at handbook size by confining himself to the essential and most important phases of the subject.

In the first chapter the author outlines the scope of his subject, describing the place of drilling in the oil producing industry. He emphasizes the need for ever closer co-ordination of geology, drilling engineering, and production engineering with actual drilling practice to provide for the efficient extraction of oil from depths which tend always to increase as the shallower concentrations are consumed, and predicts that improvements in equipment and technique, phenomenal as they have been in the past, will continue for a very long time in the future.

Four basic factors are listed which together make for the efficient penetration of the earth's crust by the rotary drill : These are : the correct bit, the correct rotating speed, the right weight on the bit, and the most satisfactory circulating fluid.

It is on the base of this able summary of essentials that the body of this handbook is constructed, and as a general comment it may be stated that the author's aptitude for stating the crux of each subject in a logical and easily understood manner persists throughout.

Chapters II to VIII deal with the components of the present-day rotary rig—power plants, circulating pumps, derricks, hoists, rotary tables, feed controls, and derrick equipment. Chapters IX to XXV deal, *seriatim*, with operation of the drilling rig, starting with lubrication and ending with safety measures. Chapters XXVI to XXVIII are devoted to geology, accounting, and a summary. There are also a glossary, some illustrations, and 206 pages of charts and tables.

It is perhaps the inclusion of so much ancillary and engineering data (Chapter XXIX onwards) that has led to some sacrifice of cogent material. It might have been better to have substituted coverage of the many methods of logging for the chapter on geology, and a review of the actual cost of drilling for the chapter on accounting. Though it is customary to include tables and charts in such a handbook, it is doubted whether it is justified to do so, and it is suggested that in future editions a companion and complete book of tables and charts should be produced, since this by itself would supply a need which is of long standing. E. C. S.

Magic Oil—Servant of the World. A. M. Leeston. Dallas, Texas : Juan Pablos Books, 1951. Pp. 237. $3.75.

This book, which includes a number of tables and an excellent bibliography and index, provides a valuable review of the world political and economic implications of the petroleum industry.

The publication is well written and easy to read, and the subject matter should be of considerable interest not only to the technical and non-technical staff of the petroleum industry but also to the great mass of students of current political affairs.

The book is divided into six parts dealing, in the following order, with the U.S. the Middle East, the Far East, Russia, Europe, and the Americas. Within these divisions the reader is led easily through the vast complications of relationships between the various activities and phases of petroleum industry development. As an additional clarification, the provision of historical backgrounds of certain present day situations, such as those of the petroleum industry of Iran, does much to make the book read easily and with the interest given to a classical novel. As is to be expected, much emphasis is laid on the American petroleum industry, but nevertheless adequate attention is paid to other petroleum producing countries.

Finally, the reviewer cannot do better than quote a paragraph in the introduction : " This brief survey proposes to show the accomplishments of the oil industry in this country (U.S.A.) and abroad and to prove that its tremendous success is the direct outcome of skilful, efficient, and alert management operating under a system of competitive free enterprise." W. H. T.

ADDITIONS TO THE LIBRARY

Annual Reviews of Petroleum Technology. Vol. 12 (Covering 1950). London: Institute of Petroleum, 1952. Pp. viii + 513.

World List of Scientific Periodicals published in the years 1900–1950. 3rd Edn. London: Butterworth's Scientific Publications, 1952. Pp. xvii + 1058.

British Standards. British Standards Institution:

B.S. 501,554: 1952. Reports on Metric Units of Volume and Standard Temperature of Volumetric Glassware. Pp. 16. 2*s*. 6*d*. net, post free.

B.S. 604: 1952. Graduated Measuring Cylinders. Pp. 13. 2*s*. net, post free.

B.S. 611: 1952. Petr. Dishes. Pp. 7. 2*s*. net, post free.

B.S. 612: 1952. Nessler Cylinders. Pp. 10. 2*s*. net, post free.

B.S. 733: 1952. Density Bottles. Pp. 18. 3*s*. net, post free.

B.S. 919: 1952. Screw Gauge Limits and Tolerances. Pp. 52. 5*s*. net, post free.

B.S. 1079: 1952. Hæmoglobinometers Haldane Type. Pp. 14. 2*s*. net, post free.

B.S. 1751: 1952. General Purpose Glass Stopcocks. Pp. 10. 2*s*. net, post free.

B.S. 1792: 1952. One-Mark Graduated Flasks. Pp. 11. 2*s*. net, post free.

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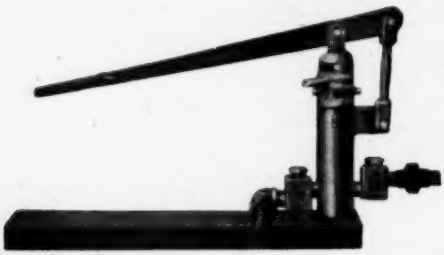

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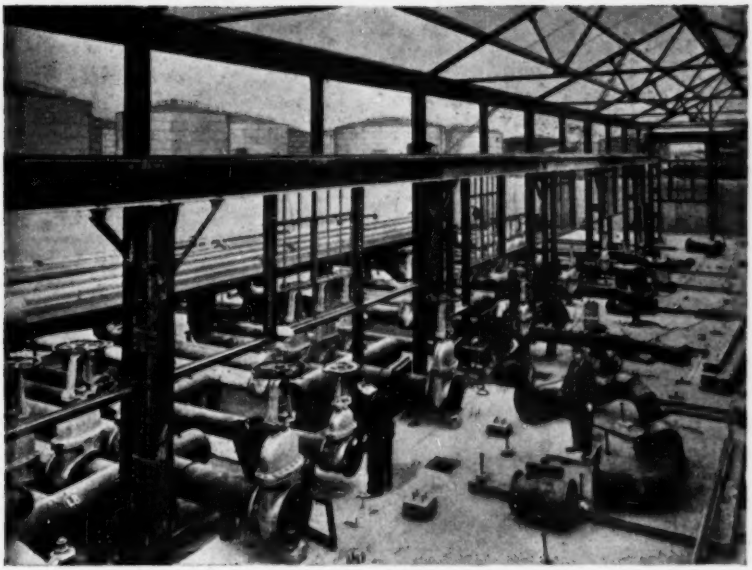

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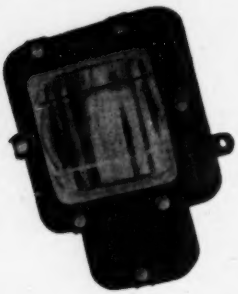

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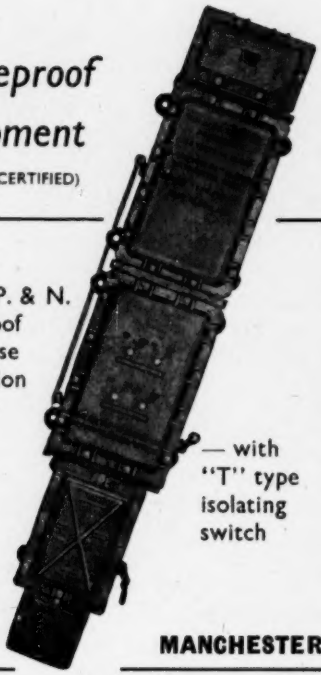

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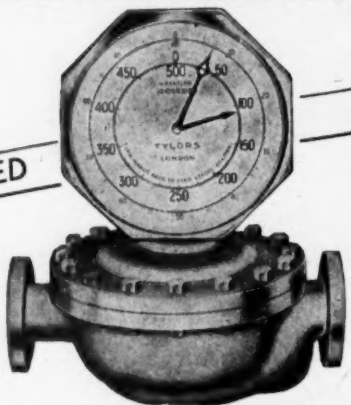

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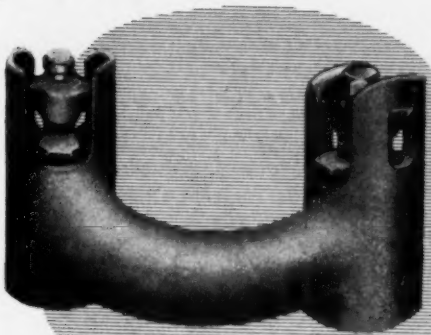

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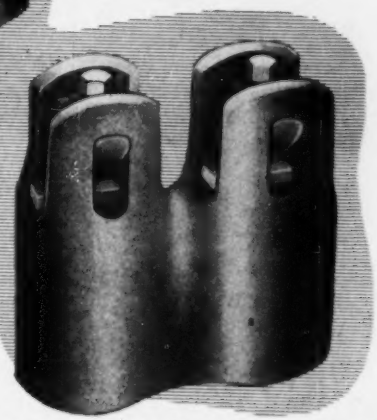

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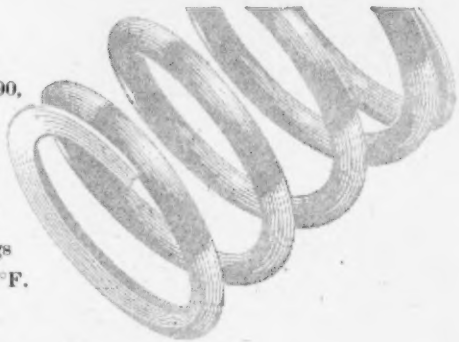

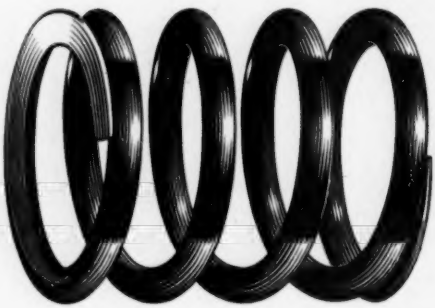

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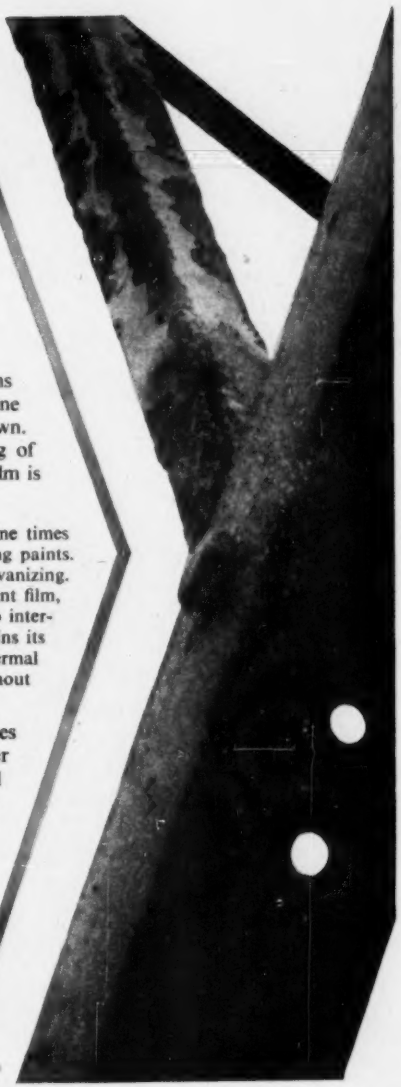

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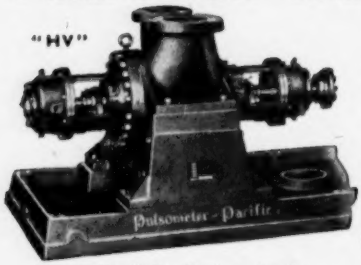

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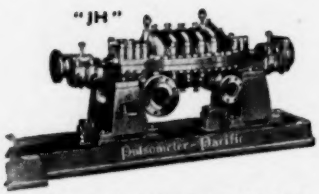

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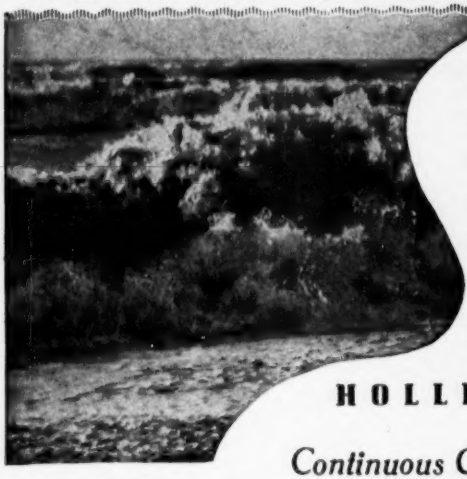

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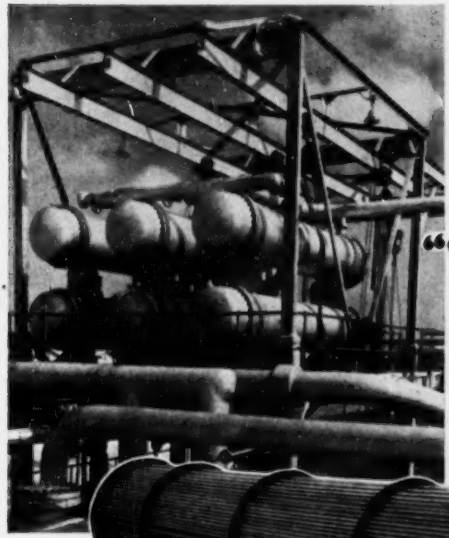

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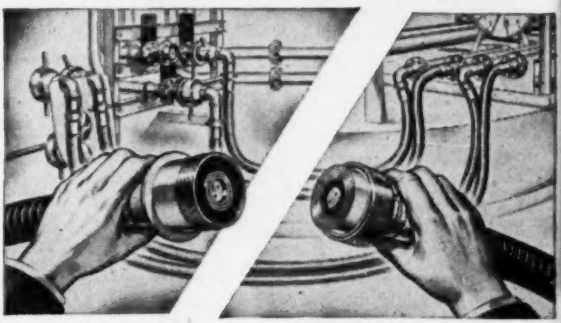

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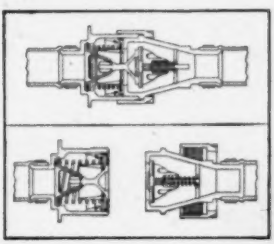

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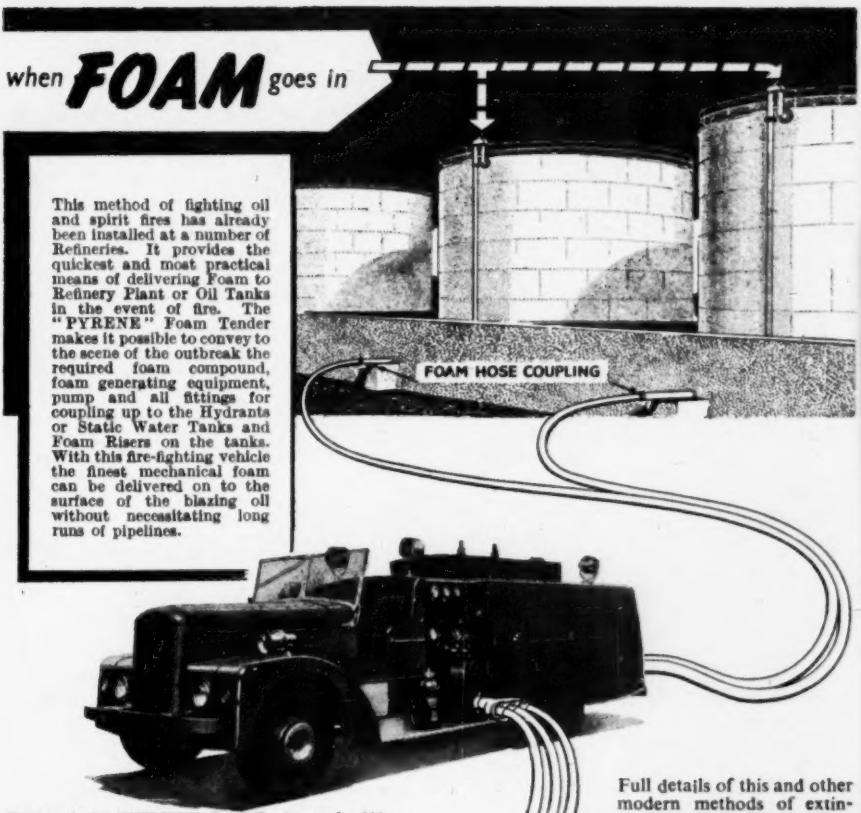

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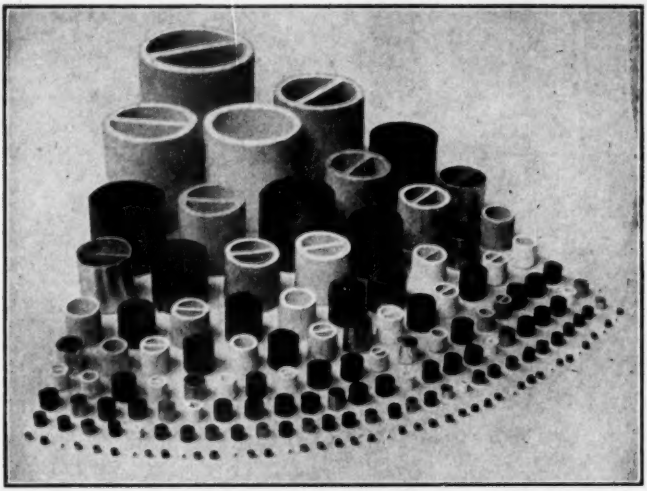

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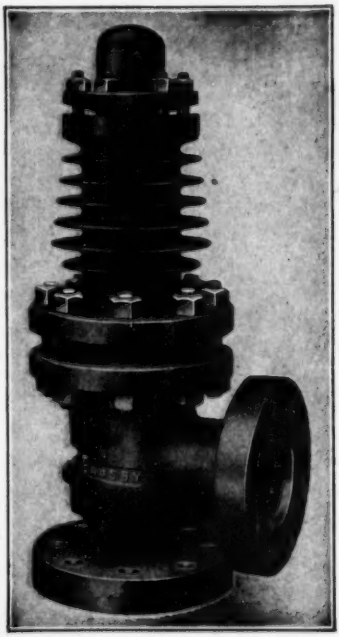

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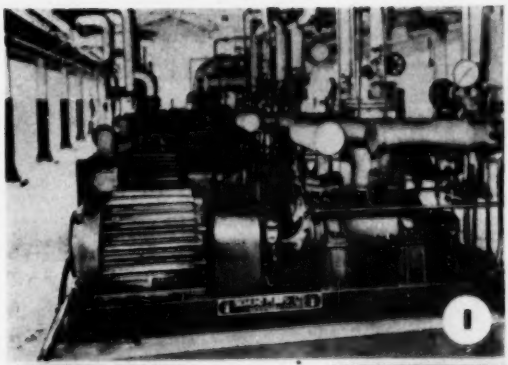

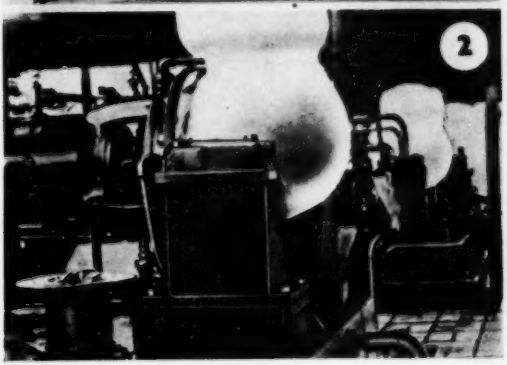

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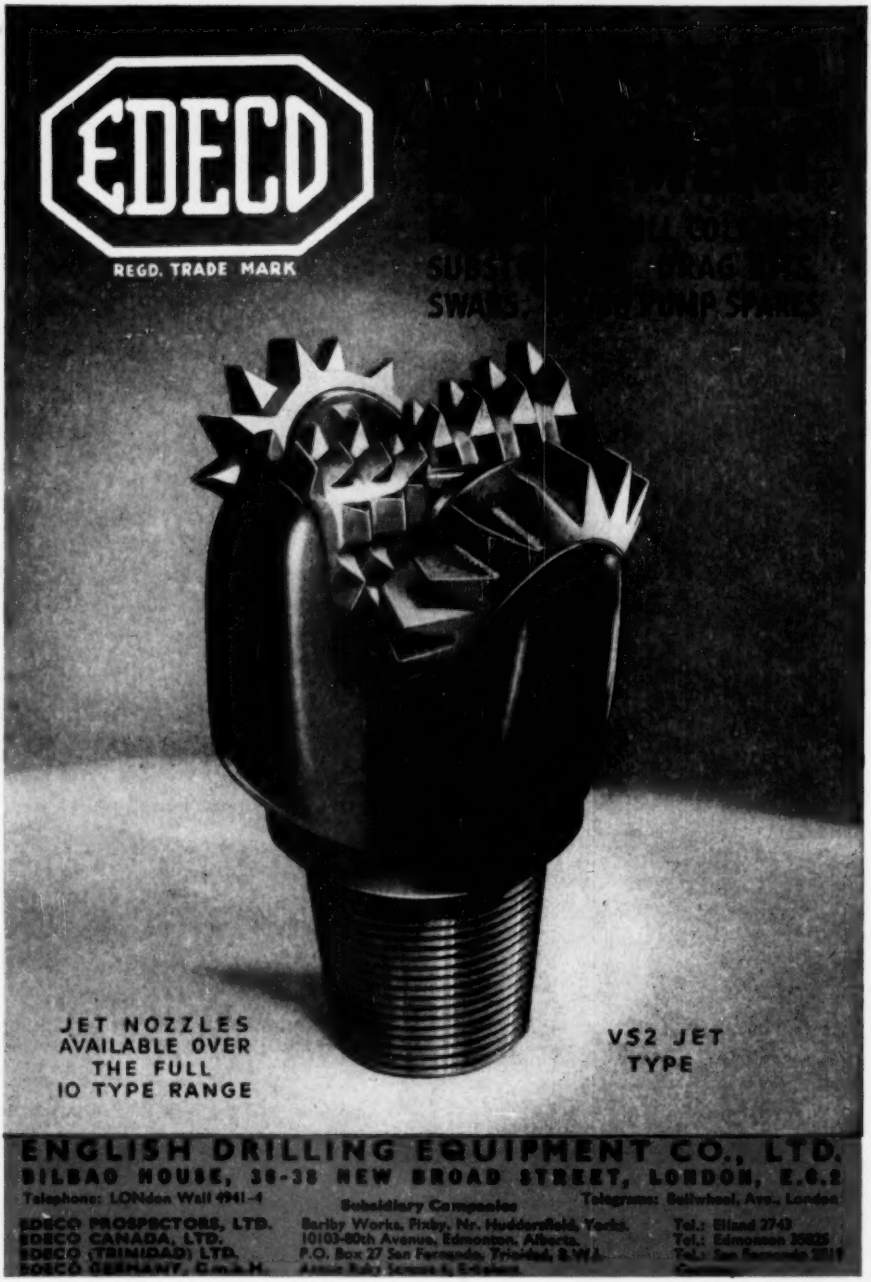
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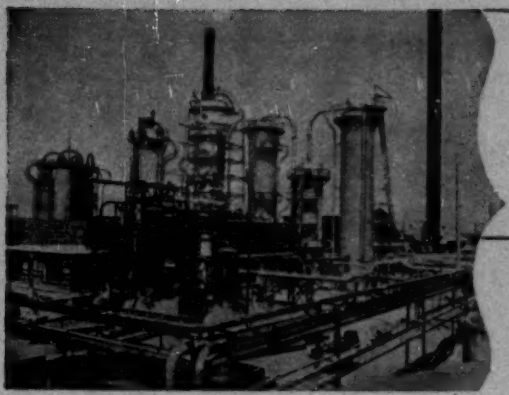

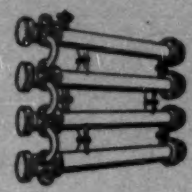

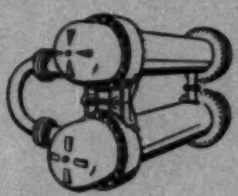

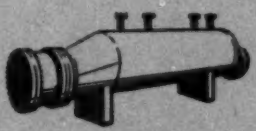

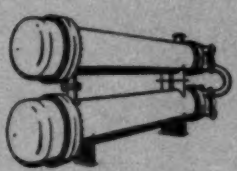

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